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|---|---|---|---|---|---|
| WGIIAR5-PartA_FINAL | Examples include greater likelihood of injury, disease, and death due to more intense heat waves and fires (very high confidence); increased likelihood of under-nutrition resulting from diminished food production in poor regions (high confidence); risks from lost work capacity and reduced labor productivity in vulnerable populations; and increased risks from food- and water-borne diseases (very high confidence) and Summary for Policymakers 57 9.3, 25.9, 26.8, 28.2, 28.4, Box 25-5 58 3.5, 10.2, 10.7, 10.10, 17.4-5, 25.7, 26.7-9, Box 25-7 59 Disaster loss estimates are lower-bound estimates because many impacts, such as loss of human lives, cultural heritage, and ecosystem services, are difficult to value and monetize, and thus they are poorly reflected in estimates of losses. Impacts on the informal or undocumented economy as well as indirect economic effects can be very important in some areas and sectors, but are generally not counted in reported estimates of losses. [SREX 4.5] 60 1 tonne of carbon = 3.667 tonne of CO2 61 10.9<br>SPM Summary for Policymakers 20 vector-borne diseases (medium confidence). Positive effects are expected to include modest reductions in cold-related mortality and morbidity in some areas due to fewer cold extremes (low confidence), geographical shifts in food production (medium confidence), and reduced capacity of vectors to transmit some diseases. But globally over the 21st century, the magnitude and severity of negative impacts are projected to increasingly outweigh positive impacts (high confidence). The most effective vulnerability reduction measures for health in the near term are programs that implement and improve basic public health measures such as provision of clean water and sanitation, secure essential health care including vaccination and child health services, increase capacity for disaster preparedness and response, and alleviate poverty (very high confidence). By 2100 for the high-emission scenario RCP8.5, the combination of high temperature and humidity in some areas for parts of the year is projected to compromise normal human activities, including growing food or working outdoors (high confidence). | 37 - 38 | Impact | | |
| WGIIAR5-PartA_FINAL | Destruction of livelihoods particularly for those depending on water�intensive agriculture. Risk of food insecurity Interactions across human vulnerabilities: deteriorating livelihoods, poverty traps, heightened food insecurity, decreased land productivity, rural outmigration, and increase in new urban poor in developing countries. Potential tipping point in rain�fed farming system and /or pastoralism Limited ability to compensate for losses in water�dependent farming and pastoral systems, and conffict over natural resources Lack of capacity and resilience in water management regimes, inappropriate land policy, and misperception and undermining of pastoral livelihoods vii Rising ocean temperature, ocean acidiffcation, and loss of Arctic sea ice [5.4.2, 6.3.1, 6.3.2, 7.4.2, 9.3.5, 22.3.2, 24.4, 25.6, 27.3.3, 28.2, 28.3, 29.3.1, 30.5, 30.6, Boxes CC-OA and CC-CR;WGI AR5 11.3.3] High susceptibility of warm-water coral reefs and respective ecosystem services for coastal communities; high susceptibility of polar systems, e.g., to invasive species Loss of coral cover, Arctic species, and associated ecosystems with reduction of biodiversity and potential losses of important ecosystem services. Risk of loss of endemic species, mixing of ecosystem types, and increased dominance of invasive organisms Interactions of stressors such as acidiffcation and warming on calcareous organisms enhancing risk Susceptibility of coastal and SIDS ffshing communities depending on these ecosystem services; and of Arctic settlements and culture viii Rising land temperatures, and changes in precipitation patterns and in frequency and intensity of extreme heat [4.3.4, 19.3.2, 22.4.5, 27.3, Boxes 23-1 and CC-WE;WGI AR5 11.3.2] Susceptibility of human systems, agro-ecosystems, and natural ecosystems to (1) loss of regulation of pests and diseases, ffre, landslide, erosion, ffooding, avalanche, water quality, and local climate; (2) loss of provision of food, livestock, ffber, and bioenergy; (3) loss of recreation, tourism, aesthetic and heritage values, and biodiversity Reduction of biodiversity and potential losses of important ecosystem services. Risk of loss of endemic species, mixing of ecosystem types, and increased dominance of invasive organisms Interaction of social-ecological systems with loss of ecosystem services on which they depend Table TS.3 (continued) Social vulnerability Economic vulnerability Environmental vulnerability Institutional vulnerability Exposure<br>61 Technical Summary TS Box TS.5 \| Human Interference with the Climate System Human inffuence on the climate system is clear (WGI AR5 SPM Section D.3;WGI AR5 Sections 2.2, 6.3, 10.3 to 10.6, 10.9). Yet determining whether such inffuence constitutes “dangerous anthropogenic interference” in the words of Article 2 of the UNFCCC involves both risk assessment and value judgments. Scientiffc assessment can characterize risks based on the likelihood, magnitude, and scope of potential consequences of climate change. Science can also evaluate risks varying spatially and temporally across alternative development pathways, which affect vulnerability, exposure, and level of climate change. Interpreting the potential danger of risks, however, also requires value judgments by people with differing goals and worldviews. Judgments about the risks of climate change depend on the relative importance ascribed to economic versus ecosystem assets, to the present versus the future, and to the distribution versus aggregation of impacts. From some perspectives, isolated or infrequent impacts from climate change may not rise to the level of dangerous anthropogenic interference, but accumulation of the same kinds of impacts could, as they become more widespread, more frequent, or more severe. The rate of climate change can also inffuence risks. This report assesses risks across contexts and through time, providing a | 78 - 79 | Impact | INTANBILE | |

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|---|---|---|---|---|---|
| WGIIAR5-PartA_FINAL | 3.5.2.5. Other Uses In addition to direct impacts, vulnerabilities, and risks in water-related sectors, indirect impacts of hydrological changes are expected for navigation, transportation, tourism, and urban planning (Pinter et al., 2006; Koetse and Rietveld, 2009; Rabassa, 2009; Badjeck et al., 2010; Beniston, 2012). Social and political problemscan result from hydrological changes. For example, water scarcity and water overexploitation may increase the risks of violent conflicts and nation-state instability (Barnett and Adger, 2007; Burke et al. 2009; Buhaug et al., 2010; Hsiang et al., 2011). Snowline rise and glacier shrinkage are very likely to impact environmental, hydrological, geomorphological, heritage, and tourism resources in cold regions (Rabassa, 2009), as already observed for tourism in the European Alps (Beniston, 2012).Although most impacts will be adverse, some might be beneficial. | 271 - 271 | Impact | | |
| WGIIAR5-PartA_FINAL | 4.3.4. Impacts on Key Ecosystem Services Ecosystem services are the benefits that people derive from ecosystems (see Glossary). Many ecosystem services are plausibly vulnerable to climate change. The Millennium Ecosystem Assessment classification (Millennium Ecosystem Assessment, 2003) recognizes provisioning services such as food (Chapter 7), fiber (Section 4.3.4.2), bioenergy (Section 4.3.4.3), and water (Chapter 3); regulating services such as climate regulation (Section 4.3.4.5), pollination, pest and disease control (Section 4.3.4.4), and flood control (Chapter 3);supporting services such as primary production (Section 4.3.2.2) and nutrient cycling (Section 4.2.4.2, and indirectly Section 4.3.2.3); and cultural services, including recreation and aesthetic and spiritual benefits (Section 10.6). Section 4.3.4.1 focuses on ecosystem services not already covered in the sections referenced above. | 337 - 337 | Impact | INTANBILE | |
| WGIIAR5-PartA_FINAL | For many locations, population and assets exposure is growing faster than the national average trends owing to coastward migration,coastal industrialization, and urbanization (e.g., McGranahan et al., 2007; Seto, 2011; Smith, 2011; see also Chapter 8; high confidence). Coastal net migration has largely taken place in flood- and cyclone-prone areas, which poses a challenge for adaptation (de Sherbinin et al., 2011).These processes and associated land use changes are driven by a combination of many social, economic, and institutional factors including taxes, subsidies, insurance schemes, aesthetic and recreational attractiveness of the coast, and increased mobility (Bagstad et al., 2007; Palmer et al., 2011). In China, the country with the largest exposed population, urbanization and land reclamation are the major drivers of coastal land use change (Zhu et al., 2012). Although coastal migration is expected to continue in the coming decades, it is difficult to capture this process in global scenarios, as the drivers of migration and urbanization are complex and variable (Black et al., 2011). | 391 - 391 | Prot-Adapt-Mitig- | | |
| WGIIAR5-PartA_FINAL | 5.4.3. Human Systems 5.4.3.1. Human Settlements Important direct effects ofclimate change on coastal settlements include dry-land loss due to erosion and submergence, damage of extreme events (such as wind storms, storm surges, floods, heat extremes, and droughts) on built environments, effects on health (food- and water-borne disease), effects on energy use, effects on water availability and resources, and loss ofcultural heritage (Hunt andWatkiss, 2010). SinceAR4, a large number of regional, national, and subnational scale studies on coastal impacts have been conducted. These are covered in the respective regional chapters. At the global scale, studies have focused either on exposure to sea level rise or extreme water levels or on the physical impacts of flooding, submergence, and erosion. | 399 - 399 | Impact | | |
| WGIIAR5-PartA_FINAL | 5.5.3.2. Institution and Governance Analysis Decisions are made within a context. Institution and governance analysis comprise a variety of approaches that aim at describing this context as well as at explaining the emergence and performance of institutions and governance structures (GS). Institution analysis is particularly relevant to coastal adaptation, because deciding between options and implementing them is an ongoing process involving complex inter�linkages between public and private decisions at multiple levels of decision making and in the context of other issues, existing policies, conflicting interests, and diverse GS (e.g, Few et al., 2007; Urwin and Jordan, 2008; Hinkel et al., 2010; see also Sections 2.2.2, 2.2.3). The non-consideration of this context may hinder or mislead adaptation decisions and implementations as reported by the emerging literature on barriers to adaptation (Section 5.5.5). Institution analysis strives to understand how this context shapes decisions, and insights gained may be employed to craft effective institutions and policies for adaptation. | 406 - 406 | Prot-Adapt-Mitig-Impac | | |
| WGIIAR5-PartA_FINAL | Regarding natural (unassisted) adaptation, several researchers have examined biophysical limits, for example, of coastal marshes (Craft et al., 2009; Langley et al., 2009; Mudd et al., 2009; Kirwan et al., 2010), and found that under certain nonlinear feedbacks among inundation, plant growth, organic matter accretion, and sediment deposition coastal wetlands can adapt to conservative rates of sea level rise (SRES A1B) if suspended sediment surpasses a certain threshold. In contrast, even coastal marshes with high sediment supplies will submerge near the 394 Chapter 5 Coastal Systems and Low-Lying Areas 5 end of the 21st century under scenarios of more rapid sea level rise (e.g., those that include ice sheet melting). | 411 - 412 | Prot-Adapt-Mitig- | | |

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|---|---|---|---|---|---|
| WGIIAR5-PartA_FINAL | 6.4.1. Ecosystem Services Marine ecosystem services (e.g., Chapter 5) include products (food, fuel, biochemical resources), climate regulation and biogeochemical processes (CO2 uptake, carbon storage, microbial water purification), coastal protection, provision of space and waterways for maritime transport, cultural services (recreational and spiritual opportunities, aesthetic enjoyment), and functions supporting all other ecosystem services (nutrient cycling, photosynthesis, habitat creation). Most components of the marine environment contribute to more than one major category of ecosystem service: for example, ocean primary productivity isclassified as a supporting service, but it affects provisioning services via changes in fisheries, generation of fossil fuel resources, regulating services via the global carbon cycle and climate regulation, and cultural services via the enjoyment of a healthy ecosystem. Rarely has economic damage of climate change to a whole ecosystem been evaluated and projected. The projected loss of tropical reef cover due to ocean acidification under SRESA1 and B2 scenarios will cause damages of US$870 and 528 billion (year 2000 value) by 2100, respectively (cost rising with parallel economic growth; Brander et al., 2012;see also Box CC-OA). Such loss is felt most strongly in the respective regions. | 470 - 470 | 'rot-Adapt-Mitig-Impa | INTANBILE | |
| WGIIAR5-PartA_FINAL | Climate change may endanger harvests of marine species with spiritual and aesthetic importance to indigenous cultures, raising ethical questions about cultural preservation (e.g., Nuttall, 1998). In coastal communities, losing the aesthetic values of marine ecosystems may harm local economies: better water quality and fewer harmful algal blooms are related to higher shellfish landings and real estate prices (Jin et al., 2008). | 471 - 471 | | INTANBILE | INDG |
| WGIIAR5-PartA_FINAL | Some heritage benefits of preserving marine ecosystems consist of the economic value of a healthy, diverse ecosystem to future generations. | 471 - 471 | | | |
| WGIIAR5-PartA_FINAL | Any climate-related biodiversity loss or pollution of marine ecosystems would decrease the bank of resources for future opportunities. For example, the research and conservation value of coral reef biodiversity and its non-use value are estimated together at US$5.5 billion annually (Cesar et al., 2003).As with spiritual and aesthetic benefits, maintaining heritage benefits under climate change poses challenges for managers concerning equity and ethics as well as multigenerational (and possibly multi-cultural) ethical questions. | 471 - 471 | Prot-Adapt-Mitig- | INTANBILE | |
| WGIIAR5-PartA_FINAL | 8.2.4.4. Built Environment, and Recreation and Heritage Sites Housing ideally provides its occupants with a comfortable, healthy, and secure living environment and protects them from injuries, losses, damage, and displacement (Haines et al., 2013). For many low-income households, livelihoods also depend on home-based enterprises, and housing is key to protecting their assets and preventing disruption of their incomes. Decent housing has particular importance for vulnerable groups, including infants and young children (Bartlett, 2008), older residents, or those with disabilities or chronic health conditions. | 577 - 577 | 'rot-Adapt-Mitig-Impa | | |
| WGIIAR5-PartA_FINAL | The increased risks that climate change brings to the built environment (Spennemann and Look, 1998;Wilby, 2007) also apply to built heritage. | 578 - 578 | Impact | | |
| WGIIAR5-PartA_FINAL | This has led to the Venice Declaration on Building Resilience at the Local Level Towards Protected Cultural Heritage and Climate Change Adaptation Strategies,which brings together UNESCO, UN-HABITAT, EC, and individual city mayors. An example is Saint-Louis in Senegal, a coastal city and World Heritage Site on the mouth of the Senegal river, which has frequent floods and large areas at risk from river and coastal flooding. There are initiatives to reduce flooding risks and relocate families from locations most at risk, but the local authority has very limited investment capacity (Diagne, 2007; Silver et al., 2013). | 578 - 578 | 'rot-Adapt-Mitig-Impact | | |
| WGIIAR5-PartA_FINAL | Spennemann, D.H.R. and D.W. Look (eds.), 1998: Disaster Management Programs for Historic Sites. Proceedings of a symposium organized by the U.S. National Park Service,Western Regional Office, San Francisco, CA in collaboration with the Western Chapter of the Association for Preservation Technology held June 27 – 29, 1997 in San Francisco, CA, Western Chapter of the Association for Preservation Technology, San Francisco, CA, USA, U.S. National Park Service, and The Johnstone Centre of Parks, Recreation, and Heritage at Charles Sturt University,Albury,Australia, U.S. Government Printing Office,Washington, DC, USA, 195 pp. | 627 - 627 | | | |
| WGIIAR5-PartA_FINAL | (2009) note that climate change may require a greater effort to protect cultural heritage. Chapter 12 discusses the impact of climate change on violent conflict, which has implications for military expenditures. | 705 - 705 | 'rot-Adapt-Mitig-Impact | | |

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| WGIIAR5-PartA_FINAL | Loss of land, cultural and natural heritage disrupting cultural practices embedded in livelihoods and expressed in narratives, world views, identity, community cohesion, and sense of place (high conffdence) [12.3.2, 12.3.4] Cultural values and expressions are dynamic and inherently adaptable and hence adaptation is possible to avoid losses of cultural assets and expressions. Nevertheless cultural integrity will be compromised in these circumstances. | 796 - 796 | Prot-Adapt-Mitig- | INTANBILE | |
| WGIIAR5-PartA_FINAL | Climate change Globalizations Technological change<br>800 Chapter 13 Livelihoods and Poverty 13 in multiple domains that promote opportunities and empowerment, and enhance security (World Bank, 2001). In addition to material deprivation, multidimensional conceptions of poverty consider a sense of belonging and socio-cultural heritage (O'Brien and Leichenko, 2003), identity, and agency, or "the culturally constrained capacity to act" (Ahearn, 2001, p. 54). The AR4 identified poverty as "the most serious obstacle to effective adaptation" (Confalonieri et al., 2007, p. 417). | 817 - 818 | 'rot-Adapt-Mitig-Impa( | INTANBILE | |
| WGIIAR5-PartA_FINAL | Application of cost-benefit or real option analysis requires evaluations in monetary terms. For market impacts, prices may need to be corrected for policies, monopoly power, or other external factors distorting market prices (Squire and van der Tak, 1975). But a cost-benefit analysis also often requires the valuation of non-market costs and benefits. This is the case for impacts on public health, cultural heritage, environmental quality and ecosystems, and distributional impacts. Valuation of non�market impact is difficult because of values and preferences heterogeneity, and subject to controversies—for example, on the value to attribute to avoided death (see Viscusi and Aldy, 2003). | 974 - 974 | Impact | | |
| WGIIAR5-PartA_FINAL | Loss ofArctic sea ice and degradation of coral reefs, as well as other natural barriers, presents a high risk to ecosystem services where many people are exposed to coastal hazards and also depend on coastal resources for livelihoods, such as Alaska, the Philippines, and Indonesia (WGI AR5 Section 11.3.3; Sections 5.4.2, 6.3.1-2, 7.4.2, 9.3.5, 22.3.2.3, 24.4, 25.6, 27.3.3, 28.2-3, 29.3.1, 30.5-6; Boxes CC-OA, CC-CR). [RFC 1, 2, and 4] viii) Risk of loss of terrestrial and inland water ecosystems, biodiversity, and the ecosystem goods, functions, and services they provide for livelihoods. Biodiversity and terrestrial ecosystem services are important for rural and urban communities globally. These services are at risk due to rising temperatures, changes in precipitation patterns, and extreme weather events. Risks are high forcommunities whose livelihoods depend on provisioning services. Human and natural systems are susceptible to loss of provisioning services such as food and fiber, regulating services such as water quality, fire, and erosion, and cultural services such as aesthetic values and tourism (WGI AR5 Section 11.3.2.5; Sections 4.3.4, 19.3.2.1, 22.4.5.6, 27.3.2.1; Boxes 23-1, CC-WE; FAQs 4.5, 4.7). [RFC 1, 3 and 4] An important common characteristic of all key risks associated with anthropogenicclimate change isthat they are determined by hazards due to changing climatic conditions on the one hand and the vulnerability of exposed societies, communities, and social-ecological systems, for No. Hazard Key vulnerabilities Key risks Emergent risks vi Drought (WGI AR5 Sections 12.4.1 and 12.4.5; Sections 3.2.7, 3.4.8, 3.5.1, 8.2.3, 8.2.4, 9.3.3, 9.3.5, 13.2.1, 19.3.2.2, and 24.4) Urban populations with inadequate water services. | 1089 - 108 | Impact | INTANBILE | |
| WGIIAR5-PartA_FINAL | Risk of loss of endemic species, mixing of ecosystem types, and increased dominance of invasive organisms Interaction of social-ecological systems with loss of ecosystem services upon which they depend Susceptibility of human systems, agro-ecosystems, and natural ecosystems to (1) loss of regulation of pests and diseases, ffre, landslide, erosion, ffooding, avalanche, water quality, and local climate; (2) loss of provision of food, livestock, ffber, bioenergy; (3) loss of recreation, tourism, aesthetic and heritage values, and biodiversity Social vulnerability Economic vulnerability Environmental vulnerability Institutional vulnerability Exposure Table 19-4 (continued)<br>1072 Chapter 19 Emergent Risks and Key Vulnerabilities 19 example, in terms of livelihoods, infrastructure, ecosystem services and management/governance systems on the other (see Table 19-4). The compilation of key risks underscores that effective adaptation and risk reduction measures would address all three components of risk (high confidence). | 1089 - 109 | 'rot-Adapt-Mitig-Impa( | INTANBILE | |

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| WGIIAR5-PartB_FINAL | {23.5.1} Climate change and sea level rise may damage European cultural heritage, including buildings, local industries, landscapes, archaeological sites, and iconic places (medium confidence), and some cultural landscapes may be lost forever (low confidence). {23.5.4; Table 23-3} Climate change may adversely affect background levels of tropospheric ozone (low confidence; limited evidence, low agreement), assuming no change in emissions, but the implications for future particulate pollution (which is more health-damaging) are very uncertain. {23.6.1} Higher temperatures may have affected trends in ground level tropospheric ozone (low confidence). {23.6.1} Climate change is likely to decrease surface water quality due to higher temperatures and changes in precipitation patterns (medium confidence), {23.6.3} and is likely to increase soil salinity in coastal regions (low confidence). {23.6.2} Climate change may also increase soil erosion (from increased extreme events) and reduce soil fertility (low confidence, limited evidence). {23.6.2}<br>1273 Europe Chapter 23 23 Observed climate change is affecting a wide range of flora and fauna, including plant pests and diseases (high confidence) {23.4.1, 23.4.4, 23.6.4} and the disease vectors and hosts (medium confidence). {23.4.2} Climate change is very likely to cause changes in habitats and species, with local extinctions (high confidence) and continental-scale shifts in species distributions (medium confidence). | 148 - 149 | Impact | | |
| WGIIAR5-PartB_FINAL | 23.4.5. Bioenergy Production The potential distribution of temperate oilseeds (e.g., oilseed rape, sunflower),starch crops (e.g., potatoes),cereals (e.g., barley), and solid biofuel crops (e.g., sorghum, Miscanthus) is projected to increase in Northern Europe by the 2080s, as a result of increasing temperatures, and to decrease in Southern Europe due to increased drought frequency Box 23-1 \| Assessment of Climate Change Impacts on Ecosystem Services by Sub-region Ecosystems provide a number of vital provisioning, regulating, and cultural services for people and society that ffow from the stock of natural capital (Stoate et al., 2009; Harrison et al., 2010). Provisioning services such as food from agro-ecosystems or timber from forests derive from intensively managed ecosystems; regulating services underpin the functioning of the climate and hydrological systems; and cultural services such as tourism, recreation, and aesthetic value are vital for societal well-being (see Section 23.5.4). | 164 - 164 | Impact | INTANBILE | |
| WGIIAR5-PartB_FINAL | 23.5.4. Cultural Heritage and Landscapes Climate change will affectculturally valued buildings (Storm et al., 2008) through extreme events and chronic damage to materials (Brimblecombe et al., 2006; Brimblecombe and Grossi, 2010; Brimblecombe, 2010a, 2010b; Grossi et al., 2011; Sabbioni et al., 2012). Cultural heritage is a non-renewable resource and impacts from environmental changes are assessed over long time scales (Brimblecombe and Grossi, 2008, 2009, 2010; Grossi et al., 2008; Bonazza et al., 2009a,b). Climate change may also affect indoor environments where cultural heritage is preserved (Lankester and Brimblecombe, 2010) as well as visitor behavior at heritage sites (Grossi et al., 2010).There is also evidence to suggest that climate change and sea level rise will affect maritime heritage in the form of shipwrecks and other submerged archaeology (Björdal, 2012). | 168 - 168 | Impact | | |
| WGIIAR5-PartB_FINAL | Europe has many unique rural landscapes, which reflect the cultural heritage that has evolved from centuries of human intervention, for example,the cork oak based Montado in Portugal,the Garrigue ofsouthern France,Alpine meadows, grouse moors in the UK, machair in Scotland, peatlands in Ireland, the polders of Belgium and the Netherlands, and vineyards. Many, if not all, of these cultural landscapes are sensitive to climate change and even small changes in the climate could have significant impacts (Gifford et al., 2011).Alpine meadows, for example, are culturally important within Europe, but although there is analysis of the economics (tourism, farming) and functionality (water runoff, flooding, and carbon sequestration) of these landscapes there is very little understanding of how climate change will affect the cultural aspects on which local communities depend. Because of their societal value, cultural landscapes are often protected and managed through rural development and environmental policies.The peat-rich uplands of Northern Europe, for example, have begun to consider landscape management as a means of adapting to the effects of climate change (e.g., the moors for the future partnership in the Peak District National Park, UK). For a discussion of the cultural implications of climate change for vineyards, see Box 23-2. | 169 - 169 | 'rot-Adapt-Mitig-Impac | INTANBILE | |
| WGIIAR5-PartB_FINAL | 23.6.1. Air Quality Climate changewill have complex and local effects on pollution chemistry, transport, emissions, and deposition.Outdoor air pollutants have adverse effects on human health, biodiversity,crop yields, and cultural heritage. | 169 - 169 | Impact | | |
| WGIIAR5-PartB_FINAL | • The vulnerability ofcultural heritage, including monuments/buildings and cultural landscapes, is an emerging concern. Some cultural landscapes will disappear. Grape production is highly sensitive to climate, but production (of grape varieties) is strongly culturally dependent and adaptation is potentially limited by the regulatory context. | 179 - 179 | 'rot-Adapt-Mitig-Impact | | |

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| WGIIAR5-PartB_FINAL | 25.4. Cross-Sectoral Adaptation: Approaches, Effectiveness, and Constraints 25.4.1. Frameworks, Governance, and Institutional Arrangements Adaptation responses depend heavily on institutional and governance arrangements(see Chapters 2, 14-16, 20). Responsibility for development and implementation of adaptation policy in Australasia is largely devolved to local governments and, in Australia, to State governments and Natural Resource Management bodies. Federal/central government supports adaptation mostly via provision of information,tools, legislation, policy guidance, and (in Australia) support for pilot projects.A standard risk management paradigm has been promoted to embed adaptation into decision-making practices (AGO, 2006; MfE, 2008b; Standards Australia, 2013), but broader systems and resilience approaches are used increasingly for natural resource management (Clayton et al., 2011; NRC, 2012). The Council of Australian Governments agreed a national adaptation policy framework in 2007 (COAG, 2007). This included establishing the collaborative National Climate Change Adaptation Research Facility (NCCARF) in 2008,which complemented Commonwealth Scientific and Industrial Research Organisation (CSIRO)'s Climate Adaptation Flagship. The federal government supported a first-pass nationalcoastal risk assessment (DCC, 2009;DCCEE, 2011), is developing indicators and criteria for assessing adaptation progress and outcomes (DIICCSRTE, 2013), and commissioned targeted reports addressing impacts and management options for natural and managed landscapes (Campbell, 2008; Steffen et al., 2009; Dunlop et al., 2012), National and World Heritage areas (ANU, 2009; BMT WBM, 2011), and indigenous and urban communities (Green et al., 2009; Norman, 2010). Most State and Territory governments have also developed adaptation plans (e.g., DSE, 2013). | 258 - 258 | Prot-Adapt-Mitig-Impac | | INDG |
| WGIIAR5-PartB_FINAL | Although multi-level and multi-sectoralcoordination is a key component of effective adaptation, it is constrained by factors such as mismatch between climate and development goals, political rivalry, and lack of national support to regional and local efforts (Brklacich et al., 2008; Brown, 2009; Sander-Regier et al., 2009; Sydneysmith et al., 2010; Craft and Howlett, 2013; Romero-Lankao et al., 2013a). Traditionally, environmental or engineering agencies are responsible forclimate issues (e.g., Mexico City, Edmonton and London, Canada), but have neither the decision-making power nor the resources to address all dimensions involved. Adaptation planning requires long-term investments by government, business, grassroots organizations, and individuals (e.g., Romero-Lankao, 2007; Burch, 2010; Croci et al., 2010; Richardson, 2010). | 352 - 352 | Prot-Adapt-Mitig-Impact | | |
| WGIIAR5-PartB_FINAL | In the Caribbean, downscaled climate projections have been generated for some islands using the Hadley Centre PRECIS (Providing REgional Climates for Impact Studies) regional model (Taylor et al., 2007; Stephenson et al., 2008). For the SRES A2 and B2 scenarios, the PRECIS regional climate model projects an increase in temperature across the Caribbean of 1°C to 4°C compared to a 1960–1990 baseline, with increasing rainfall during the latter part of the wetseason from November to January in the northern Caribbean (i.e., north of 22°N) and drier conditions in the southern Caribbean linked to changes in the Caribbean Low Level Jet (CLLJ) with a strong tendency to drying in the traditional wet season from June to October (Whyte et al., 2008; Campbell et al., 2011; Taylor et al., 2013). Projected lengthening seasonal dry periods, and increasing frequency of drought are expected to increase demand for water throughout the region under the SRESA1B scenario (Cashman et al., 2010). Decrease in crop yield is also projected in Puerto Rico for the SRES B1 (low), A2 (mid to high), and A1F1 scenarios during September although increased crop yield is suggested during February (Harmsen et al., 2009). Using a tourism demand model linked to the SRES A1F1, A2, B1, and B2 scenarios, the projected climate change heating and drying impacts are also linked to potential aesthetic, physical, and thermal effects that are estimated to cause a change in total regional tourist expenditure of about +321, +356, –118, and -146 million US$ from the least to the most severe emissions scenario, respectively (Moore, 2010). | 504 - 504 | Impact | | |
| WGIIAR5-PartB_FINAL | Ecosystem services Ecological processes or functions having monetary or non-monetary value to individuals or society at large. These are frequently classified as (1) supporting services such as productivity or biodiversity maintenance, (2) provisioning services such as food, fiber, or fish, (3) regulating services such as climate regulation or carbon sequestration, and (4) cultural services such as tourism or spiritual and aesthetic appreciation. | 640 - 640 | | INTANBILE | |
| ar4_wg2_full_report | Tourism is the major contributor to GDP and employment in many small islands. Sea-level rise and increased sea-water temperature are likely to contribute to accelerated beach erosion, degradation of coral reefs and bleaching (Table TS.2). In addition, loss of cultural heritage from inundation and flooding will reduce the amenity value for coastal users. Whereas a warmer climate could reduce the number of people visiting small islands in low latitudes, it could have the reverse effect in mid�and high-latitude islands. However, water shortages and increased incidence of vector-borne diseases are also likely to deter tourists [16.4.6]. | 69 - 69 | Impact | | |

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|---|---|---|---|---|---|
| ar4_wg2_full_report | Chacaltaya Glacier, with a mean altitude of 5,260 m above sea level, was the highest skiing station in the world until a very few years ago. After the accelerated shrinkage of the glacier during the 1990s, enhanced by the warm 1997/98 El Niño, Bolivia lost its only ski area (Figure 1.1), directly affecting the development of snow sports and recreation in this part of the Andes, where glaciers are an important part of the cultural heritage. | 98 - 98 | | | |
| ar4_wg2_full_report | There are major implications for amenities, cultural heritage, accessibility, and health of communities. These include costs, injury and trauma due to increased storm intensity and higher extreme temperatures, damage to items and landscapes of cultural significance, degraded beaches due to sea-level rise and larger storm surges, and higher insurance premiums (PIA, 2004). Increased demand for emergency services is likely. By 2100, costs of road maintenance in Australia are estimated to rise 31% for the SRES A2 scenario in a CSIRO climate simulation (Austroads, 2004). | 533 - 533 | Impact | INTANBILE | |
| ar4_wg2_full_report | SOE, 2001: Australia State of the Environment 2001: Independent Report to the Commonwealth Minister for the Environment and Heritage. Australian State of the Environment Committee, CSIRO Publishing on behalf of the Department of the Environment and Heritage, 129 pp. http:/www.ea.gov.au/soe/2001. | 549 - 549 | | | |
| ar4_wg2_full_report | Tourism is the major contributor to GDP and employment in many small islands. Sea-level rise and increased sea water temperature will cause accelerated beach erosion, degradation of coral reefs, and bleaching. In addition, a loss of cultural heritage from inundation and flooding reduces the amenity value for coastal users. Whereas a warmer climate could reduce the number of people visiting small islands in low latitudes, it could have the reverse effect in mid- and high-latitude islands. | 700 - 700 | Impact | | |
| ar4_wg2_full_report | Tourism is a major economic sector in many small islands, and its importance is increasing. Since their economies depend so highly on tourism, the impacts of climate change on tourism resources in small islands will have significant effects, both direct and indirect (Bigano et al., 2005; Viner, 2006). Sea-level rise and increased sea water temperatures are projected to accelerate beach erosion, cause degradation of natural coastal defences such as mangroves and coral reefs, and result in the loss of cultural heritage on coasts affected by inundation and flooding. These impacts will in turn reduce attractions for coastal tourism. For example, the sustainability of island tourism resorts in Malaysia is expected to be compromised by rising sea level, beach erosion and saline contamination of coastal wells, a major source of water supply for island resorts (Tan and Teh, 2001). | 712 - 712 | Impact | | |
| ar4_wg2_full_report | Almost without exception, international airports on small islands are sited on or within a few kilometres of the coast, and on tiny coral islands. Likewise, the main (and often only) road network runs along the coast (Walker and Barrie, 2006). In the South Pacific region of small islands, Lal (2004) estimates that, since 1950, mean sea level has risen at a rate of approximately 3.5 mm/yr, and he projects a rise of 25 to 58 cm by the middle of this century. Under these conditions, much of the Box 16.3. Grenada and Hurricane Ivan Hurricane Ivan struck Grenada on 7 September 2004, as a category 4 system on the Saffir-Simpson scale. Sustained winds reached 140 mph, with gusts exceeding 160 mph. An official OECS/UN-ECLAC Assessment reported the following: • 28 people killed, • overall damages calculated at twice the current GDP, • 90% of housing stock damaged, • 90% of guest rooms in the tourism sector damaged or destroyed, equivalent to approximately 29% GDP, • losses in telecommunications equivalent to 13% GDP, • damage to schools and education infrastructure equivalent to 20% GDP, • losses in agricultural sector equivalent to 10% GDP. The two main crops, nutmeg and cocoa, which have long gestation periods, will not contribute to GDP or earn foreign exchange for the next 10 years, • damage to electricity installations totalling 9% GDP, • heavy damage to eco-tourism and cultural heritage sites, resulting in 60% job losses in the sub-sector, • prior to Hurricane Ivan, Grenada was on course to experience an economic growth rate of approximately 5.7% per annum but negative growth of around −1.4% per annum is now forecast. | 713 - 713 | Impact | | |
| ar4_wg2_full_report | (2001) noted that some traditional island assets, including subsistence and traditional technologies, skills and knowledge, and community structures, and coastal areas containing spiritual, cultural and heritage sites, appeared to be at risk from climate change, and particularly sea-level rise. They argued that some of these values and traditions are compatible with modern conservation and environmental practices. | 719 - 719 | 'rot-Adapt-Mitig-Impa | INTANBILE | |

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|---|---|---|---|---|---|
| ar4_wg2_full_report | This section assesses the limits to adaptation that have been discussed in the climate change and related literatures. Limits are defined here as the conditions or factors that render adaptation ineffective as a response to climate change and are largely insurmountable. These limits are necessarily subjective and dependent upon the values of diverse groups. These limits to adaptation are closely linked to the rate and magnitude of climate change, as well as associated key vulnerabilities discussed in Chapter 19. The perceived limits to adaptation are hence likely to vary according to different metrics. For example, the five numeraires for judging the significance of climate change impacts described by Schneider et al. (2000b) - monetary loss, loss of life, biodiversity loss, distribution and equity, and quality of life (including factors such as coercion to migrate, conflict over resources, cultural diversity, and loss of cultural heritage sites) - can lead to very different assessments of the limits to adaptation. But emerging literature on adaptation processes also identifies significant barriers to action in financial, cultural and policy realms that raise questions about the efficacy and legitimacy of adaptation as a response to climate change. | 744 - 744 | Prot-Adapt-Mitig-Impact | | |
| ar4_wg2_full_report | For some impacts, qualitative rankings of magnitude are more appropriate than quantitative ones. Qualitative methods have been applied to reflect social preferences related to the potential loss of cultural or national identity, loss of cultural heritage sites, and loss of biodiversity (Schneider et al., 2000). | 796 - 796 | Impact | | |
| ar4_wg2_full_report | Ecosystem services Ecological processes or functions having monetary or non-mon�etary value to individuals or society at large. There are (i) sup�porting services such as productivity or biodiversity maintenance, (ii) provisioning services such as food, fibre, or fish, (iii) regulating services such as climate regulation or car�bon sequestration, and (iv) cultural services such as tourism or spiritual and aesthetic appreciation. | 885 - 885 | | INTANBILE | |
| ar4_wg2_full_report | INTA Usunoff, Eduardo Instituto de Hidrologie de Llanuras Vinocur, Marta Universidad Nacional de Río Cuarto Wehbe, Mónica Universidad Nacional de Río Cuarto AUSTRALIA Anderson, Rod Department of Sustainability and Environment Ash, Andrew CSIRO Baird, Mark University of New South Wales Barnett, Jon The University of Melbourne Beer, Tom CSIRO Appendix III: Reviewers of the IPCC WGII Fourth Assessment Report<br>Beggs, Paul Macquarie University Boyle, Sharon Planning Institute of Australia Brunskill, Gregg Australian Institute of Marine Science Chambers, Lynda Bureau of Meteorology Research Centre Churchman, Susan Department of Environment and Heritage South Cleland, Sam Bureau of Meteorology Cocklin, Chris Monash University Coleman, Anthony Insurance Australia Group Collins, Dean Bureau of Meteorology Crimp, Steven Queensland Centre for Climate Applications Curran, Beth Bureau of Meteorology Dunlop, Michael CSIRO Edwards, Spencer Department of Environment and Heritage Farquhar, Graham Australian National University Garnham, John Department of Primary Industries Gifford, Roger M. | 910 - 911 | | | |
| IPCC_AR6_WGII_Full_Report | This report recognises the value of diverse forms of knowledge such as scientific, as well as Indigenous knowledge and local knowledge in understanding and evaluating climate adaptation processes and actions to reduce risks from human-induced climate change. AR6 highlights adaptation solutions which are effective, feasible13, and conform to principles of justice14. The term climate justice, while used in different ways in different contexts by different communities, generally includes three principles: distributive justice which refers to the allocation of burdens and benefits among individuals, nations and generations; procedural justice which refers to who decides and participates in decision-making; and recognition which entails basic respect and robust engagement with and fair consideration of diverse cultures and perspectives. | 7 - 7 | Prot-Adapt-Mitig-Impac | | INDG |

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| Report Title (Year) | Quotation Content | Page(s) | Prot-Adapt-Mitig-Impact* | Intangible** | Indigenous*** |
|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | Maladaptive responses to climate change can create lock-ins of vulnerability, exposure and risks that are difficult and expensive to change and exacerbate existing inequalities. Maladaptation can be avoided by flexible, multi-sectoral, inclusive and long-term planning and implementation of adaptation actions with benefits to many sectors and systems. (high confidence) {1.3, 1.4, 2.6., Box 2.2, 3.2, 3.6, Box 4.3, Box 4.5, 4.6, 4.7, Figure 4.29, 5.6, 5.13, 8.2, 8.3, 8.4, 8.6, 9.6, 9.7, 9.8, 9.9, 9.10, 9.11, Box 9.5, Box 9.8, Box 9.9, Box 11.6, 13.11, 13.3, 13.4, 13.5, 14.5, 15.5, 15.6, 16.3, 17.3, 17.4, 17.6, 17.2, 17.5, CCP5.4, CCB NATURAL, CCB SLR, CCB DEEP, CWGB BIOECONOMY, CCP2.3, CCP2.3} SPM.C.4.1 Actions that focus on sectors and risks in isolation and on short-term gains often lead to maladaptation if long-term impacts of the adaptation option and long-term adaptation commitment are not taken into account (high confidence). The implementation of these maladaptive actions can result in infrastructure and institutions that are inflexible and/or expensive to change (high confidence). For example, seawalls effectively reduce impacts to people and assets in the short-term but can also result in lock-ins and increase exposure to climate risks in the long-term unless they are integrated into a long-term adaptive plan (high confidence). Adaptation integrated with development reduces lock-ins and creates opportunities (e.g., infrastructure upgrading) (medium confidence). {1.4, 3.4, 3.6, 10.4, 11.7, Box 11.6, 13.2, 17.2, 17.5, 17.6, CCP 2.3, CCB SLR, CCB DEEP} SPM.C.4.2 Biodiversity and ecosystem resilience to climate change are decreased by maladaptive actions, which also constrain ecosystem services. Examples of these maladaptive actions for ecosystems include fire suppression in naturally fire-adapted ecosystems or hard defences against flooding. These actions reduce space for natural processes and represent a severe form of maladaptation for the ecosystems they degrade, replace or fragment, thereby reducing their resilience to climate change and the ability to provide ecosystem services for adaptation. Considering biodiversity and autonomous adaptation in long-term planning processes reduces the risk of maladaptation. (high confidence) {2.4, 2.6, Table 2.7, 3.4, 3.6, 4.7, 5.6, 5.13, Table 5.21, 5.13, Box 13.2, 17.2, 17.5, Table 5.23, Box 11.2, 13.2, CCP5.4} SPM.C.4.3 Maladaptation especially affects marginalised and vulnerable groups adversely (e.g., Indigenous Peoples, ethnic minorities, low-income households, informal settlements), reinforcing and entrenching existing inequities. Adaptation planning and implementation that do not consider adverse outcomes for different groups can lead to maladaptation, increasing exposure to risks, marginalising people from certain socio-economic or livelihood groups, and exacerbating inequity. Inclusive planning initiatives informed by cultural values, Indigenous knowledge, local knowledge, and scientific knowledge can help prevent maladaptation. (high confidence) (Figure SPM.4) {2.6, 3.6, 4.3, 4.6, 4.8, 5.12, 5.13, 5.14, 6.1, Box 7.1, 8.4, 11.4, 12.5, Box 13.2, 14.4, Box 14.1, 17.2, 17.5, 18.2, 17.2., CCP2.4} SPM.C.4.4 To minimize maladaptation, multi-sectoral, multi-actor and inclusive planning with flexible pathways encourages low-regret47 and timely actions that keep options open, ensure benefits in multiple sectors and systems and indicate the available solution space for adapting to long-term climate change (very high confidence). Maladaptation is also minimized by planning that accounts for the time it takes to adapt (high confidence), the uncertainty about the rate and magnitude of climate risk (medium confidence) and a wide range of potentially adverse consequences of adaptation actions (high confidence). {1.4, 3.6, 5.12, 5.13, 5.14, 11.6, 11.7, 17.3, 17.6, CCP2.3, CCP2.4, CCB SLR, CCB DEEP; CCP5.4} 47 From AR5, an option that would | 30 - 31 | Prot-Adapt-Mitig-Impac | INTANBILE | INDG |

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| IPCC_AR6_WGII_Full_Report | Multiple climate resilient development pathways are still possible by which communities, the private sector, governments, nations and the world can pursue climate resilient development – each involving and resulting from different societal choices influenced by different contexts and opportunities and constraints on system transitions. Climate resilient development pathways are progressively constrained by every increment of warming, in particular beyond 1.5°C, social and economic inequalities, the balance between adaptation and mitigation varying by national, regional and local circumstances and geographies, according to capabilities including resources, vulnerability, culture and values, past development choices leading to past emissions and future warming scenarios, bounding the climate resilient development pathways remaining, and the ways in which development trajectories are shaped by equity, and social and climate justice. (very high confidence) {2.6, 4.7, 4.8, 5.14, 6.4, 7.4, 8.3, 9.4, 9.3, 9.4, 9.5, 10.6, 11.8, 12.5, 13.10, 14.7, 15.3, 18.5, CCP2.3, CCP3.4, CCP4.4, CCP5.3, CCP5.4, Table CCP5.2, CCP6.3, CCP7.5, Figure TS14.d} APPROVED Summary for Policymakers IPCC WGII Sixth Assessment Report Subject to Copyedit SPM-31 Total pages: 35 SPM.D.1.2 Opportunities for climate resilient development are not equitably distributed around the world (very high confidence). Climate impacts and risks exacerbate vulnerability and social and economic inequities and consequently increase persistent and acute development challenges, especially in developing regions and sub-regions, and in particularly exposed sites, including coasts, small islands, deserts, mountains and polar regions. This in turn undermines efforts to achieve sustainable development, particularly for vulnerable and marginalized communities (very high confidence). {2.5, 4.4, 4.7, 6.3, 9.4, Box 6.4, Figure 6.5, Table 18.5, CWGB URBAN, CCB HEALTH, CCP2.2, CCP3.2, CCP3.3, CCP5.4, CCP6.2} SPM.D.1.3 Embedding effective and equitable adaptation and mitigation in development planning can reduce vulnerability, conserve and restore ecosystems, and enable climate resilient development. This is especially challenging in localities with persistent development gaps and limited resources (high confidence). Dynamic trade-offs and competing priorities exist between mitigation, adaptation, and development. Integrated and inclusive system-oriented solutions based on equity and social and climate justice reduce risks and enable climate resilient development (high confidence). {1.4, 2.6, 3.6, 4.7, 4.8, Box 4.5, Box 4.8, 5.13, 7.4, 8.5, 9.4, 10.6, Box 9.3, Box 2.2, 12.5, 12.6, 13.3, 13.4, 13.10, 13.11, 14.7, 18.4, CCB HEALTH, SRCCL, CCB DEEP, CCP2, CCP5.4} Figure SPM.5: Climate resilient development (CRD) is the process of implementing greenhouse gas mitigation and adaptation measures to support sustainable development. This figure builds on Figure SPM.9 in AR5 WGII (depicting climate resilient pathways) by describing how CRD pathways are the result of cumulative societal choices and actions within multiple arenas. Panel (a): Societal choices towards higher CRD (green cog) or lower CRD (red cog) result from interacting decisions and actions by diverse government, private sector and civil society actors, in the context of climate risks, adaptation limits and development gaps. These actors engage with adaptation, mitigation and development actions in political, economic and financial, ecological, socio-cultural, knowledge and technology, and community arenas from local to international levels. Opportunities for climate resilient development are not equitably distributed around the world. Panel (b): Cumulatively, societal choices, which are made continuously, shift global development pathways towards higher | 32 - 34 | Prot-Adapt-Mitig-Impac | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | Climate resilient development in urban areas also supports adaptive capacity in more rural places through maintaining peri-urban supply chains of goods and services and financial flows (medium confidence). Coastal cities and settlements play an especially important role in advancing climate resilient development (high confidence). {6.2, 6.3, 18.3, Table 6.6, Box 9.8, CCP6.2, CCP2.1. CCP2.2, CWGB URBAN} SPM.D.3.1 Taking integrated action for climate resilience to avoid climate risk requires urgent decision making for the new built environment and retrofitting existing urban design, infrastructure and land use. Based on socioeconomic circumstances, adaptation and sustainable development actions will provide multiple benefits including for health and well-being, particularly when supported by national governments, non�governmental organisations and international agencies that work across sectors in partnerships with local communities. Equitable partnerships between local and municipal governments, the private sector, Indigenous Peoples, local communities, and civil society can, including through international cooperation, advance climate resilient development by addressing structural inequalities, insufficient financial resources, cross-city risks and the integration of Indigenous knowledge and Local knowledge. (high confidence) {6.2, 6.3, 6.4, 7.4, 8.5, 9.4, 10.5. 12.5, 17.4, 18.2, Table 6.6, Table 17.8, Box 18.1, CCP2.4, CCB GENDER, CCB INDIG, CCB FINANCE, CWGB URBAN} SPM.D.3.2 Rapid global urbanisation offers opportunities for climate resilient development in diverse contexts from rural and informal settlements to large metropolitan areas (high confidence). Dominant models of energy intensive and market-led urbanisation, insufficient and misaligned finance and a predominant focus on grey infrastructure in the absence of integration with ecological and social approaches, risks missing opportunities for adaptation and locking in maladaptation (high confidence). Poor land use planning and siloed approaches to health, ecological and social planning also exacerbates, vulnerability in already marginalised 48 Institutions: Rules, norms and conventions that guide, constrain or enable human behaviours and practices. Institutions can be formally established, for instance through laws and regulations, or informally established, for instance by traditions or customs. | 35 - 35 | Prot-Adapt-Mitig-Impac | INTANBILE | INDG |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | Institutions may spur, hinder, strengthen, weaken or distort the emergence, adoption and implementation of climate action and climate governance. APPROVED Summary for Policymakers IPCC WGII Sixth Assessment Report Subject to Copyedit SPM-34 Total pages: 35 communities (medium confidence). Urban climate resilient development is observed to be more effective if it is responsive to regional and local land use development and adaptation gaps, and addresses the underlying drivers of vulnerability (high confidence). The greatest gains in well-being can be achieved by prioritizing finance to reduce climate risk for low-income and marginalized residents including people living in informal settlements (high confidence). {5.14, 6.1, 6.2, 6.3, 6.4, 6.5, 7.4, 8.5, 8.6, 9.8, 9.9, 10.4, 18.2, Table 17.8, Table 6.6, Figure 6.5, CCB HEALTH, CCP2.2, CCP5.4, CWGB URBAN} SPM.D.3.3 Urban systems are critical, interconnected sites for enabling climate resilient development, especially at the coast. Coastal cities and settlements play a key role in moving toward higher climate resilient development given firstly, almost 11% of the global population – 896 million people – lived within the Low Elevation Coastal Zone49 in 2020, potentially increasing to beyond 1 billion people by 2050, and these people, and associated development and coastal ecosystems, face escalating climate compounded risks, including sea level rise. Secondly, these coastal cities and settlements make key contributions to climate resilient development through their vital role in national economies and inland communities, global trade supply chains, cultural exchange, and centres of innovation. (high confidence) {6.2, Box 15.2, CCP2.1, CCP2.2, Table CCP2.4, CCB SLR} SPM.D.4 Safeguarding biodiversity and ecosystems is fundamental to climate resilient development, in light of the threats climate change poses to them and their roles in adaptation and mitigation (very high confidence). Recent analyses, drawing on a range of lines of evidence, suggest that maintaining the resilience of biodiversity and ecosystem services at a global scale depends on effective and equitable conservation of approximately 30% to 50% of Earth's land, freshwater and ocean areas, including currently near-natural ecosystems (high confidence). {2.4, 2.5, 2.6, 3.4, Box 3.4, 3.5, 3.6, 12.5, 13.3, 13.4, 13.5, 13.10, CCB NATURAL, CCB INDIG} SPM.D.4.1 Building the resilience of biodiversity and supporting ecosystem integrity50 can maintain benefits for people, including livelihoods, human health and well-being and the provision of food, fibre and water, as well as contributing to disaster risk reduction and climate change adaptation and mitigation.{2.2, 2.5, 2.6, Table 2.6, Table 2.7, 3.5, 3.6, 5.8, 5.13, 5.14, 12.5, Box 5.11 CCP5.4, CCB NATURAL, CCB ILLNESS, CCB COVID, CCB GENDER, CCB INDIG, CCB MIGRATE} SPM.D.4.2 Protecting and restoring ecosystems is essential for maintaining and enhancing the resilience of the biosphere (very high confidence). Degradation and loss of ecosystems is also a cause of greenhouse gas emissions and is at increasing risk of being exacerbated by climate change impacts, including droughts and wildfire (high confidence). Climate resilient development avoids adaptation and mitigation measures that damage ecosystems (high confidence). Documented examples of adverse impacts of land-based measures intended as mitigation, when poorly implemented, include afforestation of grasslands, savannas and peatlands, and risks from bioenergy crops at large scale to water supply, food security and biodiversity (high confidence). | 35 - 36 | Prot-Adapt-Mitig-Impac | INTANBILE | |

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| IPCC_AR6_WGII_Full_Report | 23 {1.1.1, 1.3, Cross-Working Group Box ATTRIB in Chapter 1} 24 25 Since AR5, climate action has grown in salience worldwide across all levels of government as well as 26 among non-governmental organisations, small and large enterprises and citizens (high confidence). At 27 the international level the Paris Agreement and the Sustainable Development Goals (SDGs), along with other 28 targets and frameworks such as the Sendai Framework for Disaster Risk Reduction, the Convention on 29 Biological Diversity (CBD) Aichi targets, the Addis Ababa Action Agenda for finance and the New Urban 30 Agenda, provide overarching goals and policy context. These agreements also provide policy goals used by 31 this IPCC Report to assess climate action across all levels of society. {1.1.2, 1.4.1, 1.4.3} 32 33 IPCC's assessments have grown and changed substantially over the last three decades. Compared to 34 earlier IPCC assessments, this report emphasizes a common risk-solution framing across all three working 35 groups. This report focuses on solutions for risk reduction and adaptation, provides more integration across 36 the natural and social sciences, applies a more comprehensive risk framework; assesses adaptation directly in 37 the context of sectoral or regional risks; engages with different forms of knowledge, including Indigenous 38 knowledge and local knowledge; and includes an increasing focus on social justice. {1.1.4, 1.4.2, Cross- 39 Chapter Box ADAPT in Chapter 1} 40 41 Adaptation plays a key role in reducing risks and vulnerability from climate change. Implementing 42 adaptation and mitigation actions together with SDGs helps to exploit synergies, reduce trade-offs and 43 makes all three more effective. From a risk perspective, limiting atmospheric greenhouse gas 44 concentrations reduces climate-related hazards while adaptation and sustainable development reduce 45 exposure and vulnerability to those hazards. Adaptation facilitates development, which is increasingly 46 hindered by impacts and risks from climate change. Development facilitates adaptation by expanding the 47 resources and capacity to reduce climate risks and vulnerability. {1.1.3, 1.5.1, 1.5.3} 48 49 The concepts of risk and risk management have become increasingly central to climate change 50 literature, research, practice and decision making (medium confidence). Risk, defined as the potential for 51 adverse consequences for human and ecological systems, recognising the diversity of values and objectives 52 associated with such systems, provides a framework for understanding the increasingly severe, 53 interconnected and often irreversible impacts of climate change; how these impacts differentially affect 54 different regions, sectors and populations; how to allocate resources best to manage the resulting risks and 55 how to evaluate the responses that reduce residual risks for current and future generations, economies and 56 ecosystems. {1.2.1, 1.3.1, 1.4.2} 57 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 1 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 1-4 Total pages: 102 1 The concepts of adaptation, vulnerability, resilience and risk provide overlapping, alternative entry 2 points for the climate change challenge (high confidence). Vulnerability is a component of risk, but also 3 an important focus independently, improving understanding of the differential impacts of climate change on 4 people of different gender, race, wealth, social status and other attributes. Vulnerability also provides an 5 important link between climate adaptation and disaster risk reduction. Resilience, which can refer to either a 6 process or outcome, encompasses not just the concept of maintaining essential function, identity and 7 structure, but also maintaining a capacity for transformation. Such transformations bring forth | 40 - 42 | Prot-Adapt-Mitig-Impac | INTANBILE | INDG |

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| IPCC_AR6_WGII_Full_Report | 31 These include individuals and households, communities, governments at all levels, private sector businesses, 32 non-governmental organisations and religious groups and social movements. Many forms of adaptation 33 (depending on the type of climatic risk and societal context) are likely to be more effective, cost-efficient, 34 and potentially also more equitable when organized collectively. Stronger governance and adaptation finance 35 capabilities are usually associated with more ambitious adaptation plans and more effective implementation 36 of such plans. {1.4.2, 1.4.2} 37 38 Monitoring and Evaluation (M&E) of adaptation refers to a broad range of activities necessary for 39 tracking adaptation progress over time, improving adaptation effectiveness and successful iterative 40 risk management. Monitoring usually refers to continuous information gathering whereas evaluation 41 denotes more comprehensive assessments of effectiveness and equity, often resulting in recommendations 42 for decision makers. In some literatures M&E refers solely to efforts undertaken after implementation. In 43 other literatures, M&E refers both to efforts conducted before and after implementation. Since AR5, a 44 growing literature provides initial inventories of adaptation plans and implementation worldwide, but 45 information on effectiveness remains scare (high confidence). {1.4.3, Cross-Chapter Box ADAPT in Chapter 46 1} 47 48 The concept of limits to adaptation is dynamic in terms of the temporal, spatial and contextual 49 dimensions of climate change risks, impacts and response. Socioeconomic, technological, governance 50 and institutional systems or policies can be changed or transformed in responses to the different dimensions 51 of adaptation limits to climate change and extreme events. Adaptation limits can be soft or hard. Soft 52 adaptation limits occur when options may exist but are currently not available to avoid intolerable risks 53 through adaptive actions and hard adaptation limits occur when no adaptive actions are possible to avoid 54 intolerable risks. The level of greenhouse gas reduction, adaptation and risk management measures are the 55 key factors determining if and when adaptation limits are reached. When a limit (soft) is reached, then 56 intolerable risks and impacts may occur and additional adaptations (incremental or transformational) would 57 be required. Transformational adaptation can allow a system to extend beyond its soft limits and prevent soft ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 1 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 1-6 Total pages: 102 1 limits to become hard limits. The loss and damage associated with the future climate change impacts, beyond 2 the limits to adaptation, is an area of increasing focus, although yet to be fully developed in terms of methods 3 of assessing including non-economic values and identifying means to avoid and reduce both economic (loss 4 of asset, infrastructure, land etc.) and non-economic (loss of societal beliefs and values, cultural heritage, 5 biodiversity and ecosystem services) losses and damages. {1.4.4.1, 1.4.4.2} 6 7 Key concepts in this report provide a framework for assessing the urgency of climate change 8 adaptation. Adaptation is urgent to the extent that soft adaptation limits are currently being approached or 9 exceeded and that achieving levels of adaptation adequate to address these soft limits requires action at a 10 speed and scale faster than that represented by current trends (high confidence). In addition, adaptation is 11 urgent to the extent that any needed expansion of the future solution space requires near-term strengthening 12 and expansion of enablers such as governance, finance and information. Finally, adaptation is urgent to the 13 | 42 - 43 | Prot-Adapt-Mitig-Impact | | |
| IPCC_AR6_WGII_Full_Report | 18 • All these trends have impacted ecosystems, food security, water resources, water quality, 19 livelihoods, health and well-being, infrastructure, transportation, tourism and recreation, as well as 20 the culture of human societies, particularly for Indigenous peoples. | 48 - 48 | Impact | | INDG |
| IPCC_AR6_WGII_Full_Report | 31 • Coastal communities face challenging choices in crafting context-specific and integrated responses 32 to sea level rise that balance costs, benefits and trade-offs of available options and that can be 33 adjusted over time. | 48 - 48 | | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 8 9 1.3.1.1 The Nature of Climate Risk as Assessed in this Report 10 11 Greater understanding of climate-related risks is emerging; however, there are important shortcomings for 12 the information in some regions and sectors and for developing versus developed countries. These risks 13 assume significance in interaction with the cultures, values, ethics, identities, experiences, and knowledge 14 systems of affected communities and societies, as well as their governance, finances, capabilities, and 15 resources. The key risk assessment in the IPCC AR5 informed the long-term temperature goal in the 2015 16 Paris Agreement—limiting the increase in global mean temperature to well below 2°C and pursuing efforts 17 towards limiting warming to 1.5°C (Oppenheimer et al., 2014; Pachauri et al., 2014). The IPCC Special 18 Report on Global Warming of 1.5°C, responding to an invitation by UNFCCC, used new scientific 19 information to provide a specific risk assessment associated with the ambitious warming levels targeted by 20 the Paris Agreement (Hoegh-Guldberg et al., 2019), and the Special Reports on Oceans and Land further 21 advanced the methods of transparent risk assessment (Zommers et al., 2020). The current assessment 22 expands significantly from the previous reports, aiming to inform and advance understanding of the 23 following core themes: (1) the ways changes in vulnerability and exposure modulate risks of climate change 24 impacts and risk complexity in addition to warming; (2) the knowledge basis relevant to continued 25 refinement of temperature goals; (3) the effectiveness of adaptation solutions; (4) the management of risks at 26 higher levels of warming, should ambitious climate change mitigation be unsuccessful, including limits to 27 adaptation; and (5) the benefits of climate change mitigation and emissions reductions (Section 16.1). | 68 - 68 | Prot-Adapt-Mitig-Impact | | |
| IPCC_AR6_WGII_Full_Report | 37 38 The key risk assessment conveys increasing urgency given the growing visibility of climate change impacts 39 in the current world (Sections 1.1 and 16.1). Representative key risks emerging across sectors and regions 40 include risks to coastal socio-ecological systems and terrestrial and ocean ecosystems, risks associated with 41 critical infrastructure, networks, and services; risks to living standards and human health; risks to food and 42 water security; and risks to peace and migration (Section 16.5). Compared to the AR5, the emphasis on 43 human dimensions of key climate-related risks has continued and increased, for instance the potentially 44 severe impacts for cultural heritage (IPCC, 2014c; Pachauri et al., 2014; see also Section 16.4). These human 45 dimensions are essential for understanding vulnerability, impacts, and risks central to ensuring human well- 46 being, human security, sustainable development, and poverty reduction in a changing climate. | 68 - 68 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 41 The severity of climate change impacts will depend strongly on vulnerability, which is also dynamic and 42 includes the sensitivity and adaptive capacity of affected human and ecological systems (Ford et al., 2018; 43 Jurgilevich et al., 2017; McDowell et al., 2016; Viner et al., 2020). As a result, risks vary at fine scale across 44 communities and societies and also among people within societies, for example dependent on intersecting 45 inequalities and context-specific factors such as culture, gender, religion, ability and disability, or ethnicity 46 (Carr and Thompson, 2014; Jones and Boyd, 2011; Kuruppu, 2009; also Section 16.1.4). The dynamic social ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 1 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 1-33 Total pages: 102 1 distribution of impacts is the subject of increasing attention within climate assessment and responses), 2 including the role of adaptation, iterative risk management, and climate-resilient sustainable development 3 (Section 16.1). | 69 - 70 | Prot-Adapt-Mitig-Impact | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 16 17 Climate has always changed, often with severe effects on nature, including species loss 18 19 Observations provided by the historical, archaeological, and paleontological records, together with 20 paleoclimatic data, demonstrate that climatic variability has high potential to affect biodiversity and human 21 society (high confidence). The evolution of the Earth's biota has been punctuated by global biodiversity 22 crises often triggered by rapid warming (high confidence) (Benton, 2018; Figure PALEO.1; Bond and 23 Grasby, 2017; Foster et al., 2018). These so-called hyperthermal events were marked by rapid warming of 24 >1°C, which coincided with global disturbances of the carbon and water cycles, and by reduced oxygen and 25 pH in seawater (Clapham and Renne, 2019; Foster et al., 2018). Magnitudes of global temperature shifts in 26 hyperthermal events were sometimes greater than those predicted for the current century but extended over 27 longer periods of time. Rates inferred from paleo records that are coarsely resolved are inevitably lower than 28 those from direct observations during recent decades, and caution must be exercised when describing the rate 29 of recent temperature changes as unprecedented (Kemp et al., 2015). Mass extinctions, each with greater 30 than 70% marine species extinctions, occurred when the magnitude of temperature change exceeded 5.2°C 31 (Song et al., 2021), albeit species extinctions occurred at lower magnitudes of warming (medium 32 confidence). | 77 - 77 | Impact | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 7 Poleward expansions and retractions (Fordham et al., 2020; Reddin et al., 2018; Williams et al., 2018) as 8 well as migration upslope and downslope in response to warming and cooling were common adaptations 9 (Iglesias et al., 2018; Ortega-Rosas et al., 2008). During warming periods, diversity loss was common near 10 the equator (medium confidence)(Kiessling et al., 2012; Kröger, 2017; Yasuhara et al., 2020) while diversity 11 gains and forest expansion occurred in high latitudes (Brovkin et al., 2021). Comparison of contemporary 12 shells and skeletons with historical collections in museums (Barnes et al., 2011) and the analysis of skeletons 13 of long-lived organisms (Cantin et al., 2010) indicate significant climate-induced change in organismic 14 growth rates today (high agreement, medium confidence). | 78 - 78 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | 52 53 Climate change destroys unique natural archives and important cultural heritage sites 54 55 Climate change not only impacts past ecosystems and societies but also the remains they have left. The 56 progressive loss of archaeological and historical sites and natural archives of paleo environmental data WGI 57 Chapter 2 constitutes often-overlooked impacts of climate change (Anderson et al., 2017; Climate Change ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 1 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 1-42 Total pages: 102 1 Cultural Heritage Working Group International, 2019; Cross-Chapter Box SLR in Chapter 3; Hollesen et al., 2 2018). These archives include peat bogs and coastal archives lost to sea-level rise, droughts and fires, 3 degradation through permafrost thaw, and dissolution. The ancient cultural diversity documented by such 4 sites is an important resource for future adaptation (Burke et al., 2021; Rockman and Hritz, 2020). Since 5 many of these sites constitute anchors for indigenous knowledge, their loss is not just data lost to science; it 6 also interrupts intergenerational transmission of knowledge (Green et al., 2009). | 78 - 79 | 'rot-Adapt-Mitig-Impa( | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 31 32 Such experience-based and practical knowledge is obtained over generations through observing and working 33 directly within various environments. Knowledge may be place-based and rooted in local cultures, especially 34 when it reflects the beliefs of long-settled communities who have strong ties to their natural environments 35 (Orlove et al., 2010). Other times, knowledge may be embedded in institutions or oral traditions that 36 mobilise them across contexts, for example, as migrant populations bring their knowledge across different 37 regions, and have global relevance. Scientific insights often confirm findings from both IK and LK 38 (Ignatowski and Rosales, 2013), but IK and LK also provide specific, alternative ways to understand 39 environmental change including tacit and embodied aspects of knowledge (Mellegård and Boonstra, 2020), 40 that may be crucial to foster local action and which are not easily captured in scientific knowledge (including 41 cultural indicators, scales and interconnectedness between ecosystems). Multiple knowledge systems (i.e. | 81 - 81 | | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 20 21 The AR4 was the first IPCC report to explicitly discuss the value of IK and LK in adaptation and mitigation 22 processes. AR5 recognized the importance of creating synergies across disciplines in the production of 23 knowledge, acknowledging the importance of 'non-scientific sources such as Indigenous knowledge, which 24 may not follow discipline conventions but nevertheless reflects the outcomes of learning across generations 25 (Burkett et al., 2014) and explains the importance of including local and Indigenous knowledge and diverse 26 stakeholder interests, values, and in local decision-making processes (Jones et al., 2014). Such processes 27 should not only be done in partnership with IK and LK knowledge holders but, when possible, led by them 28 (Inuit Tapiriit Kanatami, 2018). Recent IPCC reports have included distinct sections dedicated to IK and LK 29 (e.g., SROCC, IPCC, 2019b). The IPCC Special Report on Climate Change and Land (SRCCL) includes a 30 section on "Local and Indigenous knowledge for addressing land degradation" (2019a) and the IPCC Special 31 Report on Ocean and Cryosphere (SROCC) describes local knowledge as 'what non-Indigenous 32 communities, both rural and urban, use on a daily and lifelong basis,' a type of knowledge which is 33 recognized as 'multi-generational, embedded in community practices and cultures, and adaptive to changing 34 conditions' (2019b). The IPCC Special Report on Global Warming of 1.5°C emphasized the high 35 vulnerability of Indigenous Peoples to climate change, and stated that disadvantaged and vulnerable 36 populations including Indigenous Peoples and certain local communities are at disproportionately higher risk 37 of suffering adverse consequences with global warming of 1.5°C and beyond (IPCC, 2018b). The report also 38 assessed evidence in relation to the importance of including IK and LK in adaptation options, explaining 39 their role in early warning systems and arguing that they are part of a range of approaches to catalyse wide- 40 scale values and consistent with adapting to and limiting global warming to 1.5°C (IPCC, 2018b). | 82 - 82 | 'rot-Adapt-Mitig-Impa( | | INDG |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 24 25 Since principles of justice are substantive normative commitments that have been debated for centuries, it 26 would be unrealistic to expect a universal consensus. Nevertheless, there is broad agreement about the core 27 issues. Just normative principles are ones that result in fair and equitable allocation of goods, vulnerabilities 28 and risks (Caney, 2014; Jafry et al., 2018; Schlosberg, 2009; Schlosberg, 2013) 29 30 It is common to distinguish between distributive justice, procedural justice and recognition (Forsyth, 2018; 31 Fraser, 1999; Olazabal et al., 2021; Reckien et al., 2017; Schlosberg, 2003; Schlosberg, 2009). The first 32 refers to the distribution of burdens and benefits; the second to who decides and participates in decision- 33 making; while recognition entails basic respect and robust engagement with and fair consideration of diverse 34 values, cultures, perspectives, and worldviews. Recognition is closely to distributive and procedural justice 35 (Hourdequin, 2016). Without recognition, actors may not benefit from the two other aspects of justice 36 (medium confidence). Recognition thus represents both a normative principle as well as an underlying cause 37 of unjust distribution and lack of democratic participation (Svarstad and Benjaminsen, 2020). However, 38 recognition is still under-represented in climate justice compared to general scholarship and debate on justice 39 principles (Benjaminsen et al., 2021; Chu and Michael, 2018). | 87 - 87 | Impact | | |
| IPCC_AR6_WGII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 1 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 1-62 Total pages: 102 1 2 Fundamental questions about equity and justice in adaptation include gender and intersectionality (see Cross- 3 Chapter Box GENDER in Chapter 18, Section 1.4.1.1 Chapter 18;) and broader critiques of who participates 4 in processes of adaptation planning and implementation, who receives investments, who and what benefits 5 from them, who makes key decisions regarding adjustments through time (Boeckmann and Zeeb, 2016; 6 Byskov et al., 2021; Eriksen et al., 2021; Nightingale et al., 2019; Pelling and Garschagen, 2019; Taylor et 7 al., 2014), and how climate justice intersects with other justice agendas. Attention is also turning to relations 8 and tensions between different adaptation approaches, scales, constraints, limits, losses, enablers and 9 outcomes (Barnett et al., 2015; Crichton and Esteban, 2017; Deshpande et al., 2018; Gharbaoui and Blocher, 10 2017; McNamara and Jackson, 2019; Mechler and Schinko, 2016; Pelling et al., 2015). Evident here is an 11 ongoing, serious knowledge gap around the long-term repercussions of adaptation interventions. There is 12 growing awareness of the need to address the potential for maladaptation (Sections 1.4.2.4; 5.13.3; 15.5.1, 13 17.5.2, Chapter 4 on Water). Concerns about maladaptation have led to renewed calls to open the “black 14 box” of decision making to examine the influence of power relationships, politics and institutional 15 culture(Biesbroek et al., 2013; Eriksen et al., 2015; Goldman et al., 2018), including the power-adaptation 16 linkage itself (Woroniecki et al., 2019), external factors outside the decision-making process (Eisenack et al., 17 2014) and the influence of leadership on adaptation processes and outcomes (Meijerink et al., 2014; Vignola 18 et al., 2017). | 98 - 99 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | 25 26 [END CROSS CHAPTER BOX ADAPT HERE] 27 28 29 1.4.4 Limits to Adaptation 30 31 The effectiveness of adaptation efforts also depends on the constraints and limits that human and natural 32 systems face when confronted with increasingly higher levels of climate risks. The concept of adaptation 33 limits strongly affects any appropriate balance among adaptation and mitigation actions in the sense that less 34 mitigation makes adaptation harder or even infeasible. Adaptation limits refer to the point at which an 35 actor’s objectives (or system needs) cannot be secured from intolerable risks through adaptive actions (WGII 36 AR6 Glossary). Adaptation limits can be soft or hard. Soft adaptation limits occur when options may exist 37 but are currently not available to avoid intolerable risks through adaptive actions and hard adaptation limits 38 occur when no adaptive actions are possible to avoid intolerable risks. Intolerable risks are those which 39 fundamentally threaten a private or social norm — threatening, for instance, public safety, continuity of 40 traditions, a legal standard or a social contract -- despite adaptive action having been taken (Dow et. al. | 99 - 99 | Prot-Adapt-Mitig-Impac | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 5 Adaptation limits depend on a complex function of interactions between social, ecological, technological and 6 climatic elements, which appear to have thresholds beyond which adaptation can be infeasible and represent 7 limits to adaptation. Such thresholds are endogenous to society and hence contingent on ethics, knowledge, 8 attitudes, culture, governance, institutions and policies (Abrahamson et al., 2009; Tschakert et al., 2017). | 100 - 100 | Prot-Adapt-Mitig- | INTANBILE | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 27 28 For assessing the projected losses and damages, residual risks also need to be taken into account. The loss 29 and damage associated with the future climate change impacts, beyond the limits to adaptation, is an area of 30 increasing focus, although yet to be fully developed in terms of methods of assessing including non- 31 economic losses and damages as well as identifying means to avoid and reduce both economic (loss of asset, 32 infrastructure, land etc.) and non-economic (loss of societal beliefs and values, cultural heritage, biodiversity 33 and ecosystem services) losses and damages (Andrei et al., 2015; Fankhauser and Dietz, 2014). There is an 34 increasing evidence in economic and non-economic losses due to climate extremes and slow onset events 35 under observed increases in global temperatures (Coronese et al., 2019; Section 8.3.4; Grinsted et al., 2019; 36 Kahn et al., 2019), however assessing non-economic losses and damages is lacking and needs more attention 37 (Serdeczny et al., 2016; Tschakert et al., 2019). The aggregate losses and damages would be higher if non- 38 economic values are considered in such assessment (Laurila-Pant et al., 2015; McShane, 2017). Solutions to 39 reduce or avoid loss and damage need a robust conceptual framework and analysis, focusing the future losses 40 rather than past losses (Preston, 2017) and emphasis on avoiding versus addressing loss and damage, and the 41 role of justice (Boyd et al., 2017), clarity on the detection and attribution (Section 8.2.1, Section 8.3.3), 42 effectiveness of risk management and adaptation (Cross-Chapter Box FEASIB in Chapter 18, Section 1.4), 43 the concepts of risk transfer, liability and financing (Cross-Chapter Box FINANCE in Chapter 17, Section 44 17.4.2), and the role of transformation (Section 1.5). | 101 - 101 | Prot-Adapt-Mitig-Impact | | |
| IPCC_AR6_WGII_Full_Report | 54 The 1.5 Special Report suggests that transformation is needed to generate the four system transitions. In 55 many literatures, transformation is considered a more expansive process than transition, with the former less 56 exclusively focused on socio-technical systems and more engaged with questions of power, politics, 57 capabilities, culture, identity and sense-making (Gillard et al., 2016; Hölscher et al., 2018; Linnér and ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 1 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 1-66 Total pages: 102 1 Wibeck, 2019). This report generally takes this more expansive view of transformation, often to engage with 2 issues of equity, climate justice and large-scale institutional and societal change (Box 18.3). | 102 - 103 | | | |
| IPCC_AR6_WGII_Full_Report | 19 20 Various literatures describe multiple, co-evolving societal elements which organize themselves into stable 21 regimes that, under some circumstance, can undergo significant change. The sustainability transitions 22 literature provides one central focus for understanding such processes and potential intervention points for 23 actors seeking change (Köhler et al., 2019). This literature identifies three, interacting scales: the micro, 24 meso and macro.(Geels, 2004; Köhler et al., 2019) The micro level reflects changing individual choices, 25 attitudes and motivations. The meso reflects socio-technical systems, 'a cluster of elements, including 26 technology, regulations, user practices and markets, cultural meanings, infrastructure, maintenance networks 27 and supply networks' The macro reflects the cultures, institutions, norms, governance and other broad 28 organising features of society. The sustainability transitions literature generally focuses on change that 29 originates and occurs within the meso scale, while the transformation literature focuses on change within and 30 among all scales. This Working Group II report often considers three interacting scales labelled personal, 31 practical and political (O'Brien and Sygna, 2013). Working Group III often employs the multi-level 32 perspectives framework (Geels, 2004) and the more actor-oriented three domains of decision-making 33 framework (Grubb et al., 2014; WGIII Section 1.6.4) to describe related societal scales. | 105 - 105 | | INTANBILE | |

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| IPCC_AR6_WGII_Full_Report | 31 Terrestrial ecosystems currently remove more carbon from the atmosphere, 2.5-4.3 Gt y-1 32 , than they 33 emit. Intact tropical rainforests, Arctic permafrost, and other healthy high carbon ecosystems provide 34 a vital global ecosystem service of preventing release of stored carbon (high confidence). Terrestrial 35 ecosystems contain stocks of ~3500 GtC in vegetation, permafrost, and soils, three to five times the amount 36 of carbon in unextracted fossil fuels (high confidence), and >4 times the carbon currently in the atmosphere 37 (high confidence). Tropical forests and Arctic permafrost contain the highest ecosystem carbon, with 38 peatlands following (high confidence). Deforestation, draining and burning of peatlands, and thawing of 39 Arctic permafrost due to climate change shifts these ecosystems from carbon-sinks to carbon-sources (high 40 confidence). {2.4.3.6; 2.4.3.8; 2.4.3.9. 2.4.4.4} 41 42 Evidence indicates that climate change is affecting many species, ecosystems, and ecological processes 43 that provide ecosystem services connected to human health, livelihoods, and well-being (medium 44 confidence). These services include climate regulation, water and food provisioning, pollination of crops, 45 tourism and recreation. It is difficult establish end-to-end attribution from climatic changes to changes in a 46 given ecosystem service and to identify the location and timing of impacts. This limits specific adaptation 47 planning, but protection and restoration of ecosystems could build resilience of service provision.{2.2; 2.3; 48 2.4.2.7; 2.4.5; 2.6.3; 2.6.4; 2.6.5; 2.6.6; 2.6.7; Cross-Chapter Box NATURAL this Chapter; Cross-Chapter 49 Box ILLNESS this Chapter; Cross-Chapter Box EXTREMES this Chapter; Cross-Chapter Box COVID in 50 Chapter 7; Cross-Chapter Box MOVING PLATE in Chapter 5} 51 52 Projected Risks 53 54 Climate change increases risks to fundamental aspects of terrestrial and freshwater ecosystems, with 55 the potential for species' extinctions to reach 60% at 5°C GSAT warming (high confidence), biome 56 shifts (changes in the major vegetation form of an ecosystem) on 15% (at 2ºC warming) to 35% (at 57 4ºC warming) of global land (medium confidence), and increases in the area burned by wildfire of 35% ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 2 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 2-6 Total pages: 237 1 (at 2ºC warming) to 40% (at 4ºC warming) of global land (medium confidence). {2.5.1; 2.5.2; 2.5.3; 2 2.5.4; Figure 2.6; Figure 2.7; Figure 2.8; Figure 2.9; Figure 2.11; Table 2.5; Table 2.S.2; Table 2.S.4; Cross- 3 Chapter Box DEEP in Chapter 1; Cross-Chapter Paper 1} 4 5 Extinction of species is an irreversible impact of climate change, the risk of which increases steeply 6 with rises in global temperature. It is likely that the percentage of species at high risk of extinction (median 7 and maximum estimates) will be 9% (max 14%) at 1.5°C, 10% (max 18%) at 2°C, 12% (max 29%) at 3.0°C, 8 13% (max 39%) at 4°C and 15% (max 48%) at 5°C (Figure 2.7). Among groups containing largest numbers 9 of species at high risk of extinctions for mid-levels of warming (3.2°C) are: invertebrates (15%), specifically 10 pollinators (12%), amphibians (11%, but salamanders are at 24%) and flowering plants (10%). All groups 11 fare substantially better at 2°C, with extinction projections reducing to <3% for all groups, except 12 salamanders at 7% (medium confidence) (Figure 2.8a). Even the lowest estimates of species' extinctions 13 (9%) are 1000x natural background rates. Projected species' extinctions at future global warming levels are 14 consistent with projections from AR4, but assessed on many more species with much greater geographic 15 coverage and a broader range of climate models. {2.5.1.3; Figure 2.6; Figure 2.7; Figure 2.8; Cross- | 144 - 145 | Prot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGII_Full_Report | 14 15 There is new evidence that species can persist in refugia where conditions are locally cooler, when they 16 are declining elsewhere (high confidence) {2.6.2}. Protecting refugia, for example where soils remain wet 17 during drought or fire risk is reduced, and in some cases creating cooler microclimates, are promising 18 adaptation measures {2.6.3; 2.6.5; CCP1; CCP5.2.1}. There is also new evidence that species can persist 19 locally because of plasticity, including changes in phenology or behavioural changes that move an individual 20 into cooler micro-climates, and genetic adaptation may allow species to persist for longer than might be 21 expected from local climatic changes (high confidence) {2.4.2.6; 2.4.2.8, 2.6.1}. There is no evidence to 22 indicate that these mechanisms will prevent global extinctions of rare, very localised species at their climatic 23 limits or species inhabiting climate/habitat zones that are disappearing (high confidence). {2.4.2.8, 2.5.1, 24 2.5.3.1, 2.5.4, 2.6.1, 2.6.2, 2.6.5} 25 26 Since AR5, many adaptation plans and strategies have been developed to protect ecosystems and 27 biodiversity but there is limited evidence of the extent to which adaptation is taking place and virtually 28 no evaluation of the effectiveness of adaptation measures in the scientific literature (medium 29 confidence). This is an important evidence gap that needs to be addressed to ensure a baseline is available 30 against which to judge effectiveness and develop and refine adaptation in future. Many proposed adaptation 31 measures have not been implemented (low confidence) {2.6.2; 2.6.3; 2.6.4; 2.6.5; 2.6.6; 2.6.8; 2.7} 32 33 Ecosystem restoration and resilience building cannot prevent all impacts of climate change, and 34 adaptation planning needs to manage inevitable changes to species distributions, ecosystem structure 35 and processes (very high confidence). Actions to manage inevitable change include local modification of 36 microclimate or hydrology, adjustment of site management plans and facilitating the dispersal of vulnerable 37 species to new locations, both by increasing habitat connectivity or by active translocations of species. | 146 - 146 | Prot-Adapt-Mitig-Impac | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 43 44 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 2 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 2-15 Total pages: 237 1 2 Figure 2.1: Map of global land use change from 1982-2016. Based on satellite records of global tree canopy (TC), 3 short vegetation (SV) and bare ground (BG) cover (from Song et al., 2018). a) Mean annual estimates of cover (% of 4 pixel area at 0.05° resolution). b) Long-term change estimates (% of pixel area at 1.5° resolution), with pixels showing 5 a statistically significant trend (n = 35 years, two-sided Mann–Kendall test, P < 0.05) in TC, SV or BG. The dominant 6 changes are Tree canopy gain with Short vegetation loss; Bare Ground gain with Short vegetation loss; Tree canopy 7 gain with Bare Ground loss; Bare Ground gain with Tree canopy loss; 5, Short vegetation gain with Bare Ground loss; 8 and Short vegetation gain with TC loss. Grey indicates areas with no significant change between 1982-2016. | 153 - 154 | | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 31 32 Introduction 33 34 Extreme events are now causing profound negative effects across all realms of the world (marine, terrestrial, 35 freshwater and polar) (medium confidence) (WGI, Chapter 9, 11; WGII AR6 Section 2.3.1, 2.3.2, 2.3.3.5, 36 Chapter 3, Chapters 9–12). Changes to population abundance, species distributions, local extirpations and 37 extinctions are leading to long-term, potentially irreversible shifts in the composition, structure and function 38 of natural systems (medium confidence) (Frolicher and Laufkotter, 2018; Harris et al., 2018a; Maxwell et al., 39 2019; Smale et al., 2019). These effects have widespread ramifications for ecosystems and the services they 40 provide – physical habitat, erosion control, carbon storage, nutrient cycling and water quality, with knock-on 41 effects on tourism, fisheries, forestry and other natural resources (Kaushal et al., 2018; Heinze et al., 2021; 42 Pörtner et al., 2021). | 161 - 161 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 34 35 During their range shifts, forest pests remain climate-sensitive. For example, the distribution of Western 36 Spruce Budworm is limited at its warm range edges by adverse effects of mild winters on overwinter 37 survival, and at its cool range limits by ability to arrive at a cold-resistant stage before winter arrives 38 (Régnière and Nealis, 2019). We might therefore expect tree mortality from insect outbreaks to be most 39 severe in sites climatically less suitable for the plants, where plants would be under more stress. However, 40 (Jaime et al., 2019), using separate SDMs (MaxEnt) for the insects and plants, found that mortality of Scots 41 Pine from bark beetles was highest in sites most climatically suitable for the trees as well as for the insects. | 166 - 166 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 44 45 Range shifts in a poleward and upward direction, following expected trajectories given the local and regional 46 climate trends, are strongly occurring in freshwater fish populations in North America (Lynch et al., 2016b), 47 Europe (Comte and Grenouillet, 2013; Gozlan et al., 2019) and Central Asia (Gozlan et al., 2019). Cold 48 water fish, such as coregonids and smelt have been negatively affected at the equatorial borders of their 49 distributions (Jeppesen et al., 2012). Upward elevational range shifts in rivers and streams have been 50 observed. Systematic shifts towards higher elevation and upstream were found for 32 stream fish species in 51 France following regional variation in climate change (Comte and Grenouillet, 2013). Bull trout (Salvelinus confluentus) in Idaho (USA), were estimated to have lost 11–20% (8–16% decade-1 52 ) of the headwater stream 53 lengths necessary for cold water spawning and early juvenile rearing, with the largest losses occurring in the 54 coldest habitats (Isaak et al., 2010). Range contractions of the same species have been found in the Rocky 55 Mountain watershed (Eby et al., 2014). Likewise, the distribution of the stonefly Zapada glacier, endemic to 56 alpine streams of Glacier National Park in Montana (USA), has been reduced over several decades by ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 2 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 2-28 Total pages: 237 1 upstream retreat to higher, cooler sites as water temperatures have increased and glacial masses decreased 2 (Giersch et al., 2015). | 166 - 167 | | | |
| IPCC_AR6_WGII_Full_Report | 14 15 2.4.2.2 Observed Local Population and Global Species' Extinctions Driven by Climate Change 16 17 Disappearances of local populations within a species range are more frequent and better documented than 18 whole species' extinctions, and attribution to climate change is possible for sites with minimal confounding 19 non-climatic stressors. Changes of temperature extremes are often more important to these local extinction 20 rates than changes of mean annual temperature (see Sections 2.3.1, 2.3.2, 2.3.3.5, 2.4.2.6, Cross-chapter Box 21 EXTREMES this Chapter; Parmesan et al., 2013). In a study of 538 plant and animal species, sites with local 22 extinctions were associated with smaller changes of mean annual temperature but larger and faster changes 23 of hottest yearly temperatures than sites where populations persisted (Román-Palacios and Wiens, 2020). | 167 - 167 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 24 Near warm range limits, 44% of species had suffered local extinctions. In both temperate and tropical 25 regions, sites with local extinction had greater increases in maximum temperatures than those without (Tmax 26 increased 0.456°C and 0.316°C vs. Tmean increase of 0.153 °C and 0.061 °C for temperate (n=505 sites) and 27 tropical (n=76 sites), respectively, P < 0.001) (Román-Palacios and Wiens, 2020). | 167 - 167 | | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 28 29 Wiens (2016) assumed that population extinctions were primarily driven by climate change when they 30 occurred at elevational or latitudinal "warm edge" range limits, and were in relatively undisturbed sites that 31 were stated by authors to be under increasing climatic stress. By this criterion, climate-caused local 32 extinctions were widespread among plants and animals, detected in 47% of 976 species examined. The 33 percentage of species suffering these extinctions was higher in the tropics (55%), than in temperate habitats 34 (39%), higher in freshwater (74%), than in marine (51%) or terrestrial (46%) habitats and higher in animals 35 (50%) than in plants (39%). The difference between plants and animals varied with latitude: in the temperate 36 zone a much higher proportion of animals than plants suffered range-limit extinctions (38.6% of 207 animal 37 species versus 8.6% of 105 plants, $p < 0.0001$) while at tropical sites local extinction rates were 38 (nonsignificantly) higher in plants (59% of 155 species) than in animals (52% of 349 species), the reverse of 39 their temperate zone relationship. Rates varied among animal groups, from 35% in mammals through 43% in 40 birds to 56% in insects and 59% in fish (Wiens, 2016). | 167 - 167 | | | |
| IPCC_AR6_WGII_Full_Report | 3 4 Two terrestrial and freshwater species have gone extinct, with climate change implicated as a key driver. The 5 cloud-forest-restricted Golden toad (Incilius periglenes) was extinct by 1990 in a nature preserve in Costa 6 Rica, driven by successive extreme droughts. This occurred in the absence of chytridiomycosis infection, 7 caused by the fungal pathogen Batrachochytrium dendrobatidis (BD), verified during field censuses of 8 golden toad populations in the process of extinction and through genetic analyses of museum specimens, 9 although Bd was present in other frog species in the region (medium evidence, high agreement) (Pounds et 10 al., 1999; Pounds et al., 2006; Puschendorf et al., 2006; Richards-Hrdlicka, 2013). The interaction between 11 expansion of chytrid fungus globally and local climate change is implicated in the extinction of a wide range 12 of tropical amphibians (see Section 2.4.2.7.1 Case study 2 Chytrid fungus and climate change). | 168 - 168 | | | |
| IPCC_AR6_WGII_Full_Report | 45 46 Behavioural plasticity such as nest-site selection can provide a partial buffer from the effects of increasing 47 temperature, but there are environmental and physical limits to this plasticity (medium confidence) 48 (Refsnider and Janzen, 2016; Telemeco et al., 2017). Plasticity in heat tolerance (e.g. due to reversible 49 acclimation or acclimatisation) can also potentially compensate for rising temperatures (Angilletta Jr, 2009), 50 but ectotherms have relatively low acclimation in thermal tolerance and acclimation is expected to only 51 slightly reduce overheating risk in even the most plastic taxa (low confidence) (Gunderson and Stillman, 52 2015). | 173 - 173 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 27 28 Warmer temperatures have increased blood-feeding insect harassment of reindeer with compounding 29 consequences: (1) increased insect bite rates lead to higher parasite loads, (2) time spent by raindeer in trying 30 to escape biting flies reduces foraging while simulataneously increasing energy expenditure, (3) the 31 combination of (1) and (2) lead to poor body condition, that subsequently leads to (4) reduced winter 32 survival and fecundity (Mallory and Boyce, 2017). As temperatures warm and connectivity increases 33 between the Arctic and the rest of the world, tourism, resource extraction, and increased commercial 34 transport will create additional risks of biological invasion by infectious agents and their hosts (Pauchard et 35 al., 2016). These increases in introduction risk compounded with climate change have already begun to harm 36 indigenous peoples dependent on hunting and herding livestock (horses and reindeer) that are suffering 37 increased pathogen infection (Deksne et al., 2020; Stammler and Ivanova, 2020). | 178 - 178 | Impact | | INDG |
| IPCC_AR6_WGII_Full_Report | 38 39 2.4.2.7.3 Biodiversity-disease links 40 Anthropogenic impacts, such as disturbances caused by climate change, can reduce biodiversity through 41 multiple mechanisms and increase disease risk to humans (limited evidence, low agreement) but more 42 research is needed to understand the underlying mechanisms (Civitello et al., 2015; Young et al., 2017b; 43 Halliday et al., 2020; Rohr et al., 2020; Glidden et al., 2021). Known wildlife hosts of human-shared 44 pathogens and parasites overall comprise a greater proportion of local species richness (18–72% higher) and 45 abundance (21–144% higher) in sites under substantial human use (agricultural and urban lands) compared 46 with nearby undisturbed habitats (Gibb et al., 2020). | 178 - 178 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 3 4 In the absence of evolutionary constraints, climate debts can be cancelled by genetically-based increases in 5 thermal tolerance and ability to perform in high ambient temperatures. In species already showing local 6 adaptation to climate, populations currently living at relatively cool sites should be able to evolve to adopt 7 traits of populations currently at warmer sites, as their local experience of climate changes (Singer, 2017; 8 Socolar et al., 2017). | 182 - 182 | Prot-Adapt-Mitig- | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 43 44 2.4.3.2 Global Patterns of Observed Biome Shifts Driven by Climate Change 45 46 2.4.3.2.1 Observed biome shifts predominantly driven by climate change 47 Th IPCC Fifth Assessment Report and a meta-analysis found that vegetation at the biome level shifted 48 poleward latitudinally and upward altitudinally due to anthropogenic climate change at 19 sites in boreal, 49 temperate, and tropical ecosystems from 1700 to 2007 (Gonzalez et al., 2010a; Settele et al., 2014). In these 50 areas, temperature increased 0.4° to 1.6ºC above the pre-industrial period (Gonzalez et al., 2010a; Settele et 51 al., 2014). Field research since the IPCC Fifth Assessment Report detected additional poleward and upslope 52 biome shifts over periods of 24 to 210 years at numerous sites (described below) but were not directly 53 attributed to anthropogenic climate change as the studies were not designed nor conducted properly for 54 attribution. | 183 - 183 | | | |
| IPCC_AR6_WGII_Full_Report | 6 7 Other biome shifts consistent with climate change and not substantially affected by local land use include 8 northward shifts of deciduous forest into boreal conifer forest in Canada (5 km between 1970-2012, (Sittaro 9 et al., 2017) and 20 km between 1970-2014, (Boisvert-Marsh et al., 2019)) and northward shifts of 10 temperate conifer into boreal conifer forest in Canada (21 km between 1970-2015, (Boisvert-Marsh and de 11 Blois, 2021)). Research detected upslope shifts of boreal and sub-alpine conifer forest into alpine grassland 12 at 143 sites on four continents (41 m, 1901-2018, (Lu et al., 2021)) and individual sites in Canada (54 m, 13 1900-2010, (Davis et al., 2020)), China (300 m, 1910-2000 (Liang et al., 2016); 33 m, 1985-2014, (Du et 14 al., 2018)), Nepal (50 m, 1860-2000, (Sigdel et al., 2018)), Russia (150 m, 1954-2006, (Gatti et al., 2019)) 15 and the United States (19 m, 1950-2016, (Smithers et al., 2018); 38 m, 1953-2015, (Terskaia et al., 2020)). | 184 - 184 | | | |
| IPCC_AR6_WGII_Full_Report | 19 20 In summary, anthropogenic climate change has caused latitudinal and elevational biome shifts in at least 19 21 sites in boreal, temperate, and tropical ecosystems between 1700 and 2007, where temperature increased 0.4° 22 to 1.6ºC above the pre-industrial period (robust evidence, high agreement). Additional cases of 5 to 20 km 23 northward and 20 to 300 m upslope biome shifts between 1860 and 2016, under approximately 0.9ºC mean 24 global temperature increase above the pre-industrial period, are consistent with climate change (medium 25 evidence, high agreement). | 184 - 184 | | | |
| IPCC_AR6_WGII_Full_Report | 35 36 Upslope and poleward forest shifts have occurred where timber harvesting or livestock grazing was 37 abandoned, allowing regeneration of trees at sites in Canada (Brice et al., 2019; Wang et al., 2020b), France 38 (Feuillet et al., 2020), Italy (Vitali et al., 2017), Spain (Ameztegui et al., 2016), the United States (Wang et 39 al., 2020b) and mountain areas across Europe (Cudlin et al., 2017). Intentional use of fire drove an upslope 40 forest shift in Peru (Bush et al., 2015) while mainly human-ignited fires drove conversion of shrubland to 41 grassland in a drought-affected area of the United States (Syphard et al., 2019b). In eastern Canada, timber 42 harvesting and wildfire drove conversion of mixed conifer-broadleaf forests to broadleaf-dominated forests 43 (Brice et al., 2020; Wang et al., 2020b). | 184 - 184 | | | |
| IPCC_AR6_WGII_Full_Report | 44 45 Shrub encroachment onto savanna has occurred at numerous sites, particularly across the Southern 46 Hemisphere, mainly between 1992 and 2010 (Criado et al., 2020). Globally, overgrazing initiates shrub 47 encroachment by reducing grasses more than woody plants, while fire exclusion maintains the shrub cover 48 (D'Odorico et al., 2012; Caracciolo et al., 2016; Bestelmeyer et al., 2018). The magnitude of woody cover 49 change in savannas is not correlated to mean annual temperature change (Criado et al., 2020), however, 50 higher atmospheric CO2 increases shrub growth in savannas (Nackley et al., 2018; Manea and Leishman, 51 2019). A global remote sensing analysis of biome changes from all causes, including agricultural and grazing 52 expansion and deforestation, estimated that 14% of pixels changed between 1981 and 2012, although this 53 approach can overestimate global changes since it uses a new biome classification system, which doubles the 54 conventional biome classifications (Higgins et al., 2016). In addition to climate change, land use change 55 causes vegetation changes at the biome level (robust evidence, high agreement). | 184 - 184 | | | |

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| --- | --- | --- | --- | --- | --- |
| IPCC_AR6_WGII_Full_Report | 13 14 The global extent of grasslands is declining significantly because of climate change (medium confidence). In 15 temperate and boreal zones, where about half of treelines are shifting, they are overwhelmingly expanding 16 poleward and upward, with accompanying loss of montane grassland (robust evidence, high agreement); 17 whereas tropical treelines have been generally stable (medium evidence, medium agreement) (Harsch et al., 18 2009; Rehm & Feeley 2015; Silva et al., 2016; Andela et al., 2017; Song et al., 2018; Aide et al., 2019; 19 Gibson and Newman, 2019). The Eurasian steppes experienced a 1% increase in woody cover per decade 20 since 2000 (Liu et al., 2021) and Inner Mongolian grasslands in China experienced broad encroachment as 21 well (Chen et al., 2015). Climatic drivers of woody expansion in temperature limited grasslands, particularly 22 alpine grasslands, are most frequently attributed to warming (robust evidence, high agreement, high 23 confidence) (D'Odorico et al., 2012; Hagedorn et al., 2014), increases in water and nutrient availability from 24 thawing permafrost (medium evidence, high agreement) (Zhou et al., 2015b; Silva et al., 2016) and rising 25 CO2 (medium evidence, medium agreement) (Frank et al., 2015; Aide et al., 2019). Interactions between land 26 use changes: land abandonment, grazing management shifts, and fire suppression, and climate change are 27 contributing factors (Liu et al., 2021) 28 29 Remote sensing shows overall increasing trends in both the annual maximum NDVI and annual mean NDVI 30 in global grasslands ecosystems between 1982 and 2011 (Gao et al., 2016). Multiple lines of evidence 31 indicate that changes in grassland productivity are positively correlated with increases in mean annual 32 precipitation (Hoover et al., 2014; Brookshire and Weaver, 2015; Gang et al., 2015; Gao et al., 2016; Wilcox 33 et al., 2017; Wan et al., 2018). Increasing temperatures positively impact grassland production and biomass, 34 especially in temperature limited regions (Piao et al., 2014; Gao et al., 2016). However, grasslands in hot 35 areas are expected to decrease production with increases in temperature (limited evidence, low agreement) 36 (Gang et al., 2015). Nevertheless, grassland responses to warming and drought are being ameliorated by 37 increasing CO2 and associated improved water use efficiency (Roy et al., 2016). For example, in a cool 38 temperate grassland experiment, warming led to a longer growing season and elevated CO2 further extended 39 growing by conserving water, which enabled most species to remain active longer (medium evidence, 40 medium agreement) (Reyes-Fox et al., 2014). | 187 - 187 | Impact | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 43 44 2.4.3.7 Observed Changes in Boreal and Temperate Forests 45 46 The IPCC Fifth Assessment Report found increased tree mortality, wildfire and plant phenology changes in 47 boreal and temperate forests (Settele et al., 2014). Expanding on those conclusions, this Assessment, using 48 analyses of causal factors, attributes to anthropogenic climate change the following observed changes in boreal and temperate forests in the 20th and 21st 49 centuries: upslope and poleward biome shifts at sites in Asia, 50 Europe, and North America (Section 2.4.3.2.1); range shifts of plants (Section 2.4.2.1); earlier blooming and 51 leafing of plants (Section 2.4.2.4); poleward shifts in tree-feeding insects (Section 2.4.2.1); increases in 52 insect pest outbreaks (Section 2.4.4.3.3); increases in area burned by wildfire in western North America 53 (Section 2.4.4.2.1); increased drought-induced tree mortality in western North America (Section 2.4.4.3.1); 54 and thawing of permafrost that underlies extensive areas of boreal forest (IPCC Sixth Assessment Report, 55 Working Group I, Chapter 2, Section 2.4.3.9). Atmospheric CO2 from anthropogenic sources has also 56 increased net primary productivity (Section 2.4.4.5.1). In summary, anthropogenic climate change has 57 caused substantial changes to temperate and boreal forest ecosystems, including biome shifts and increases ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 2 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 2-50 Total pages: 237 1 in wildfire, insect pest outbreaks, and tree mortality, at a global mean surface temperature increase of 0.9º C 2 above the pre-industrial period (robust evidence, high agreement). | 188 - 189 | | | |
| IPCC_AR6_WGII_Full_Report | 10 11 For some vegetation changes, land use and land management changes have exerted more influence than 12 climate change. These include upslope and poleward forest shifts in Europe following abandonment of 13 timber harvesting or livestock grazing (Section 2.4.3.2.2), changes in wildfire in Europe affected by fire 14 suppression, fire prevention, and agricultural abandonment (Section 2.4.4.2.3), and forest species 15 composition changes in Scotland due to nitrogen deposition from air pollution (Hester et al., 2019). Remote 16 sensing suggests that the area of temperate and boreal forests increased in Asia and Europe between 1982 17 and 2016 (Song et al., 2018) and in Canada between 1984 and 2015 (Guindon et al., 2018), but forest 18 plantations and regrowth are probable drivers (Song et al., 2018). | 189 - 189 | | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 55 56 In large lowland tropical peatland basins that are less impacted by anthropogenic activities (i.e., Amazon and 57 Congo river basins), the direct impact of climate change is that of a decreased carbon sink (limited evidence, ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 2 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 2-51 Total pages: 237 1 medium agreement) (Roucoux et al., 2013; Gallego-Sala et al., 2018; Wang et al., 2018a; Dargie et al., 2019; 2 Ribeiro et al., 2021). As for the temperate and boreal regions, climatic drying also tends to promote peat 3 oxidation and carbon loss to the atmosphere (medium evidence, medium agreement) (section 2.3.1.3.4) 4 (Helbig et al., 2020; Zhang et al., 2020). In Europe, increasing mean annual temperatures in the Baltic, 5 Scandinavia, and Continental Europe (Section 12.4.5.1) have led to widespread lowering of peatland water 6 tables at intact sites (Swindles et al., 2019), Sphagnum moss desiccation and die off (Bragazza, 2008; Lees et 7 al., 2019), and increased fire intensity and frequency resulting in rapid carbon loss (Davies et al., 2013; 8 Veraverbeke et al., 2021). Nevertheless, longer growing seasons and warmer, wetter climates have increased 9 carbon accumulation and promoted thick deposits regionally, as reported for some North American sites 10 (limited evidence, medium agreement) (Cai and Yu, 2011; Shiller et al., 2014; Ott and Chimner, 2016). | 189 - 190 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 18 In many instances, permafrost degradation triggers thermokarst land subsidence associated with local 19 wetting (robust evidence, high agreement) (Jones et al., 2013; Borge et al., 2017; Olvmo et al., 2020; 20 Olefeldt et al., 2021). Permafrost thaw in peatland-rich landscapes can also cause local drying through 21 increased hydrological connectivity and runoff (Connon et al., 2014). In the first decades following thaw, 22 increases in methane, CO2, and nitrous oxide emissions have been recorded from peatland sites, depending 23 on surface moisture conditions (Schuur et al., 2009; O'Donnell et al., 2012; Elberling et al., 2013; Matveev 24 et al., 2016; Euskirchen et al., 2020; Hugelius et al., 2020). Conversely, some evidence suggests increased 25 peat accumulation after thaw (Jones et al., 2013; Estop-Aragonés et al., 2018; Väliranta et al., 2021). There 26 is also a need to consider the impact of wildfire on permafrost thaw, due to its effect on soil temperature 27 regime (Gibson et al., 2018), wildfire as a}, as fire intensity and frequency have increased across the boreal 28 and Arctic biomes (limited evidence, high agreement) (Kasischke et al., 2010; Scholten et al., 2021). | 190 - 190 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 24 25 Up through the IPCC Fifth Assessment Report (Settele et al., 2014), detection and attribution analyses had 26 found that anthropogenic climate change, with global temperature increases of 0.3°-0.9ºC above the pre- 27 industrial period and increases in aridity exceeding the effects of local non-climate change factors, caused 28 three cases of drought-induced tree mortality of up to 20% in the period 1945-2007, in western North 29 America (van Mantgem et al., 2009), the African Sahel (Gonzalez et al., 2012), and North Africa (le Polain 30 de Waroux and Lambin, 2012). Increased wildfire and pest infestations, driven by climate change, also 31 contributed to the North American tree mortality (van Mantgem et al., 2009). In addition, a meta-analysis of 32 published cases found that drought consistent with, but not formally attributed, to climate change, had 33 caused tree mortality at 88 sites in boreal, temperate and tropical ecosystems (Allen et al., 2010), with 49 34 additional cases found by the IPCC Fifth Assessment report (Settele et al., 2014). | 197 - 197 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 35 36 Since the IPCC Fifth Assessment Report (Settele et al., 2014), global meta-analyses have found at least 15 37 (Allen et al., 2015) and 25 (Hartmann et al., 2018) additional sites of drought-induced tree mortality around 38 the world. These and other global analyses found more rapid mortality than previously (Allen et al., 2015), 39 rising background mortality (Allen et al., 2015), mortality increasing with drought severity (Greenwood et 40 al., 2017), mortality of tropical trees increasing with temperature (Locosselli et al., 2020), mortality 41 increasing with tree size for many species (Bennett et al., 2015), mortality predominantly at the dry edge of 42 species ranges (Anderegg et al., 2019a), and three-fourths of drought-induced mortality cases leading to a 43 change in the dominant species (Batllori et al., 2020). Multiple non-climate factors contribute to tree 44 mortality, including timber cutting, livestock grazing, and air pollution (Martinez-Vilalta and Lloret, 2016). | 197 - 197 | | | |
| IPCC_AR6_WGII_Full_Report | Globally, tropical dry forests lost, from all causes, 95,000 km2 45 , 8% of their total area, from 1982 to 2016, the 46 most extensive area of mortality of any biome (Song et al., 2018). | 197 - 197 | | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 42 43 In western North America, increased infestations of bark beetles and other tree-feeding insects that benefit 44 from increased winter temperatures (IPCC AR6 WGI 3.3.1.1) and longer growing seasons (IPCC AR6 WGI 45 2.3.4.3.1) have killed drought-stressed trees (Section 2.4.2.1; Anderegg et al., 2015; Kolb et al., 2016; Lloret 46 and Kitzberger, 2018; Redmond et al., 2018; Stephens et al., 2018; Fettig et al., 2019; Restaino et al., 2019; 47 Stephenson et al., 2019). Increasing temperatures have allowed bark beetles to move further north and higher 48 in elevation, survive through the winter at sites where they would previously have died, and reproduce more 49 often (Raffa et al., 2008; Bentz et al., 2010; Jewett et al., 2011; Macfarlane et al., 2013; Raffa et al., 2013; 50 Hart et al., 2017; Stephenson et al., 2019; Teshome et al., 2020; Koontz et al., 2021). Under warmer 51 conditions, some insects that were previously innocuous have become important agents of tree mortality 52 (Stephenson et al., 2019; Trugman et al., 2021). Field observations show mixed effects of bark beetle- 53 induced tree mortality on subsequent fire-caused tree mortality (Andrus et al., 2016; Meigs et al., 2016; 54 Candau et al., 2018; Lucash et al., 2018; Talucci and Krawchuk, 2019; Wayman and Safford, 2021). From 55 1997 to 2018, ~5% of western U.S. forest area died from bark beetle infestations (Hicke et al., 2020). In 56 most circumstances, trees that have been weakened by drought are more vulnerable to being killed by bark 57 beetles (Anderegg et al., 2015; Kolb et al., 2016; Lloret and Kitzberger, 2018; Redmond et al., 2018; ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 2 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 2-60 Total pages: 237 1 Stephens et al., 2018; Fettig et al., 2019; Restaino et al., 2019; Stephenson et al., 2019; Koontz et al., 2021). | 198 - 199 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 22 23 The Amazon as a whole was a net carbon emitter from 2003 to 2008 (Exbrayat and Williams, 2015; Yang et 24 al., 2018b), primarily due to expansion of agricultural and livestock areas, which caused over two-thirds of 25 deforestation from 1990 to 2005 (De Sy et al., 2015; De Sy et al., 2019). Four sites in the Amazon also 26 showed net carbon emissions from 2010 to 2018, from deforestation and fire (Gatti et al., 2021). In the Amazon, deforestation emitted 0.17 ± 0.05 Gt y-1 27 carbon from 2001 to 2015 (Silva Junior et al., 2020) while fires emitted 0.12 ± 0.14 Gt y-1 28 carbon from 2003 to 2015 (Aragao et al., 2018). An analysis of the Amazon carbon loss from deforestation and degradation estimated a loss of 0.5 Gt y-1 29 from 2010 to 2019, with 30 degradation accounting for three-fourths (Qin et al., 2021). Intact old-growth Amazon rainforest has been a 31 net carbon sink (Hubau et al., 2020) but may have become a net carbon source from 2010 to 2019 (Qin et al., 32 2021). | 201 - 201 | | | |
| IPCC_AR6_WGII_Full_Report | 14 15 Global terrestrial GPP increased 2% from 1951 to 2010 and continued increasing at least through 2016, with 16 increased atmospheric CO2 showing a greater influence than natural factors (Li et al., 2017; Fernandez- 17 Martinez et al., 2019; Liu et al., 2019a; Cai and Prentice, 2020; Melnikova and Sasai, 2020). Global forest 18 area increased 7% from 1982 to 2016, mainly from forest plantations and regrowth in boreal and temperate 19 forests in Asia and Europe (Song et al., 2018), while regrowth in secondary forests > 20 years old, mainly in boreal, temperate, and sub-tropical regions, generated a net removal of 7.7 Gt y-1 20 CO2 from the atmosphere 21 from 2001 to 2019 (Harris et al., 2021). Vegetation growth that exceeds the modelled CO2 fertilisation, gaps 22 in field data, and incomplete knowledge of plant mortality and soil carbon responses introduce uncertainties 23 into quantifying the magnitude of CO2 fertilisation (Walker et al., 2021). A combination of CO2 fertilisation 24 of global vegetation and secondary forest regrowth has increased global vegetation productivity (medium 25 evidence, medium agreement). | 202 - 202 | | | |
| IPCC_AR6_WGII_Full_Report | 57 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 2 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 2-65 Total pages: 237 1 Field research since the IPCC Fifth Assessment Report has detected biome shifts at numerous sites, 2 poleward and upslope, that are consistent with increased temperatures and altered precipitation patterns 3 driven by climate change, and support prior studies that attributed such shifts to anthropogenic climate 4 change (high confidence). These new studies help fill prior geographic and habitat gaps, for example 5 documenting upward shifts in the forest/alpine tundra ecotone in the Andes, Tibet and Nepal, and northward 6 shifts in the deciduous/boreal forest ecotones in Canada. Globally, woody encroachment into open areas 7 (grasslands, arid regions and tundra) is likely being driven by climate change and increased CO2 in concert 8 with changes in grazing and fire regime (medium confidence) (Section 2.4.3). | 203 - 204 | | | |
| IPCC_AR6_WGII_Full_Report | 12 Analyses of causal factors have attributed increasing tree mortality at sites in Africa and North America to 13 anthropogenic climate change and field evidence has detected tree mortality from drought, wildfire, and 14 insect pests in temperate and tropical forests around the world (high confidence). Water stress, leading to 15 plant hydraulic failure, is the a principal mechanism of drought-induced tree mortality, along with indirect 16 effects of climate change mediated through community interactions (high confidence) ( Section 2.4.4.3). | 204 - 204 | Impact | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 17 18 Terrestrial ecosystems sequester and store globally critical stocks of carbon but these stocks are at risk from 19 deforestation and climate change (high confidence). Tropical deforestation, draining, and burning of 20 peatlands produce almost all of the carbon emissions from land use change. In the Arctic, increased 21 temperatures have thawed permafrost at numerous sites, dried some areas, and increased fire, causing net 22 emissions of carbon from soils (high confidence) (Sections 2.4.4.4, 2.5.3.4). | 204 - 204 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 23 24 Globally, increases in temperature, aridity, and drought have increased the length of fire seasons and doubled 25 potentially burnable area (medium confidence). Increases in burnt area have been attributed to anthropogenic 26 climate change in North America (high confidence). In parts of Africa, Asia, Australia, and South America, 27 area burned have also increased, consistent with anthropogenic climate change. Deforestation, peat burning, 28 agricultural expansion or abandonment, fire suppression, and inter-decadal cycles, strongly influence fire 29 occurrence. Areas with the greatest increases in fire season length include the Amazon, western North 30 America, western Asia, and East Africa. (Section 2.4.4.2) 31 32 The changes we have observed, and project to continue, in biodiversity and ecosystem health pose a risk of 33 declines in human health and well-being: e.g. tourism, recreation, food, livelihoods and quality of life 34 (medium confidence). Clear attribution of these impacts is often not possible, but inference can be made by 35 comparison of observed changes in biodiversity / ecosystem health and known services from those particular 36 ecosystems. | 204 - 204 | Impact | | |
| IPCC_AR6_WGII_Full_Report | Range = 26–46 years medium evidence high agreement high confidence Anthropogenic climate change, acting through increased heat and aridity at global mean surface temperature increases of 0.6- 0.9ºC, has increased the area burned by wildfire over natural levels, increasing burned area up to 11 times in one extreme year and doubling over natural levels in a 32-year period western north America 1984-2017 robust evidence high agreement high confidence Anthropogenic climate change has caused drought-induced tree mortality of up to 20% in three regions, through global mean surface temperature increases of 0.3-0.9ºC above the pre-industrial period and increases in aridity, more than non-climate change factors North America and Africa ca. 1945-2007 medium evidence high agreement medium confidence Anthropogenic climate change has caused latitudinal and elevational vegetation biome shifts in at least 19 sites in boreal, temperate, and tropical ecosystems, between 1700 and 2007, through local temperature increases of 0.4 to 1.6ºC above the pre-industrial period more than non�climate change factors Global 1500-2007 robust evidence high agreement high confidence Anthropogenic climate change and wildfire together have altered vegetation species composition in at least two regions, reducing post-fire natural regeneration and species richness of tree and other plant species, at global mean surface temperature increases of 0.3-0.9ºC western North America, Africa 1966-2015 medium evidence high agreement medium confidence ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 2 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 2-67 Total pages: 237 Beetles & moths shifting poleward and upward has brought new pest species into some forests; warming winters and longer growing season has increased destructive outbreaks of beetles and moths in temperate and boreal forests North America, Europe Varies by study medium-high confidence Exotic species are responding differently from native species in both abundance changes and phenological changes, but not in a consistent fashion North America low/medium evidence low agreement The most cold-adapted species are generally declining in population abundances and contracting their ranges poleward and upward: (e.g. sea-ice dependent, mountain-top restricted, upper headwaters, coldest lakes) Arctic, Himalayas , Antarctic, Alps medium confidence Diseases of both wildlife and humans have emerged into new areas they have not been in historically Global past 20-100 years medium confidence Warming has amplified the trophic state lakes are already in. Eutrophic lakes have become more productive while oligotrophic lakes tend to become more nutrient limited Global Past 20-50 years robust evidence high agreement high/medium confidence Woody encroachment into open (grassland, desert) systems has occurred, with climate change as one of the drivers, along with changes in grazing and other land uses Global medium confidence In boreal, coniferous areas changes in forestry practices and climate change have caused an increase in terrestrial derived dissolved organic matter (DOM) transport into rivers and lakes leading to their browning Boreal Past decades robust evidence high agreement high confidence Climate change induced warming leads to shifts in thermal regime of lakes Global Past decades robust evidence high agreement high confidence Climate change causes gains and losses in freshwater water level Global Past decades limited evidence low confidence Greenhouse gas emissions from freshwater ecosystems are equivalent to around 20% of global burning fossil-fuel CO2 emission Global Past decades medium evidence medium agreement | 205 - 207 | Prot-Adapt-Mitig-Impact | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 43 44 Regional threats from climate change have been reported for 40% of amphibians in China, (Wu, 2020), 33% 45 of European freshwater fish species (Janssen et al., 2016) and 56-69% of Odonates in Australia, (Bush et al., 46 2014b). Assessment of site-specific extirpation likelihoods for 88 aquatic insect taxa projected that climate- 47 change induced hydrological alteration would result in a 30–40% loss of taxa in warmer, drier ecoregions 48 and 10–20% loss in cooler, wetter ecoregions (medium evidence) (Pyne and Poff, 2017). In Africa's 49 Albertine Rift, 51% (n=551) of fish are expected to be impacted by climate change, with 5.5% at high risk 50 due to their sensitivity and poor adaptative capability (high agreement) (Carr et al., 2013). | 209 - 209 | 'rot-Adapt-Mitig-Impa( | | |
| IPCC_AR6_WGII_Full_Report | 15 16 In this Chapter, risk to species, with implications for ecosystems, is assessed using three different 17 approaches. First is an assessment of the geographic distributions of species' losses at different levels of 18 GAST warming, termed 'biodiversity loss, measured as the proportion of species within a given location 19 becoming classified as 'endangered' or 'critically endangered' (sensu IUCN). This measure provides estimates 20 of which sites are at most risk of losing substantial numbers of species locally, leading to degradation of that 21 ecosystems' ability to function. Second is an assessment of risk of proportions of species' becoming extinct 22 globally at different levels of GAST warming, measured using the IUCN criteria for 'critically endangered', 23 and termed 'species' extinction risk'. This measure is closest to assessing the complete loss of a species in the 24 wild, and can be used to compare to past (paleo) extinction rates. Third is an assessment of proportions of 25 species becoming rare or endangered globally (not just locally), and is the foundation for the Burning 26 Embers on biodiversity risk in Figure 2.11. These three approaches provide complementary information of 27 the overall risks to biodiversity and ecosystem integrity under different warming levels. | 210 - 210 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 29 30 Using data from geological time scales, Song et al. (2021) predicted that a warming of 5.2 °C above pre- 31 industrial would result in mass extinction comparable to that of the five mass extinctions over the past 540 32 My, on the order of 70–85% of species going extinct, in the absence of non-climatic stressor. Mathes et al. | 213 - 213 | | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 2 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 2-78 Total pages: 237 1 2 2.5.2.3 Risk to Arid Regions 3 4 Shifts in arid system structure and functioning that have been observed to date (section 2.4.3.3) are projected 5 to continue and include widespread woody plant encroachment, notably in savanna systems in Africa, 6 Australia and South America, and attributed to interacting land use change, climate change, and $CO_2$ 7 fertilisation effects (Fensholt et al., 2012a; Fang et al., 2017; Stevens et al., 2017). Arid Mongolian Steppe 8 grassland did not respond to experimentally elevated $CO_2$ (Song et al., 2019). Woody encroachment is 9 projected to continue or not reverse in North American drylands (Caracciolo et al., 2016), and in southern 10 African arid ecosystems (Moncrieff et al., 2014b). Dryland woody encroachment may increase carbon 11 stocks, depending on emissions scenario (Martens et al., 2021), but reduce soil water and biodiversity of 12 grassland-dependent species diversity (Archer et al., 2017). Warm season (C4) grass expansion into arid 13 shrublands risks sudden ecosystem transformation due to introduced wildfire (Bradley et al., 2016), a risk 14 anticipated for grass-invaded desert ecosystems of Australia and south-western United States (Horn and St. | 216 - 217 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 29 Boreal forests insulate and stabilize permafrost and reduce fluctuations of ground temperature: the amplitude 30 of variation of ground surface temperatures was 28°C in a forested site, compared to 60°C in nearby 31 grassland (Section 2.5.2.7; Bonan, 1989; Stuenzi et al., 2021a; Stuenzi et al., 2021b). Likewise, a shift in 32 moist tropical forests towards vegetation with drought-tolerant traits could possibly reduce 33 evapotranspiration, increase albedo, alter heat transfer at the surface and lead to a negative feedback to 34 precipitation (Section 2.5.2.6; Jia et al., 2019). In savannas, restoration of woody vegetation has been shown 35 to enhance cloud formation and precipitation in response to enhanced transpiration and turbulent mixing, 36 leading to a positive feedback on woody cover (Syktus and McAlpine, 2016). While this has not yet been 37 systematically explored, similar feedbacks might also emerge from a $CO_2$-induced woody cover increase in 38 savannas (low confidence) (Section 2.5.2.5). | 234 - 234 | | | |
| IPCC_AR6_WGII_Full_Report | 21 22 Tropical lakes tend to be hotspots of freshwater biodiversity (Vadeboncoeur et al., 2011; Brawand et al., 23 2014; Sterner et al., 2020); ancient tropical lakes such as Malawi, Tanganyika, Victoria, Titicaca, Towuti 24 and Matano hold thousands of animal species found nowhere else (Vadeboncoeur et al., 2011). While 25 biodiversity and several ecosystem services can be considered synergistic (food webs, tourism, aesthetical 26 and spiritual value (Langhans et al., 2019), others can be considered antagonistic in case of a strong 27 ecosystem service demand (such as water abstraction, water use, food security in terms of over-exploitation). | 237 - 237 | | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII _Full_Report | 18 19 In addition to “material” and economic services such as eco-tourism, nature also provides cultural services 20 such as recreation, spirituality and well-being. Specifically, being in “direct contact with natural 21 environments” (versus urban environment) has a high positive and causal impact on human well-being (e.g. | 243 - 243 | Impact | INTANBILE | |
| IPCC_AR6_WGII _Full_Report | 19 20 2.6.2 Adaptation for Biodiversity Conservation 21 22 A variety of approaches have been identified as potential adaptation measures which people can take to 23 reduce the risks of climate change to biodiversity. (Heller and Zavaleta, 2009 ) (quoted in AR5) identified 24 113 categories of recommendation for adaptation from a survey of 112 papers and reports. Since this time 25 the literature has greatly expanded, with thousands of relevant publications. Whilst there is increasing 26 interest in adaptation for biodiversity conservation and a wide range of plans and strategies, there is less 27 evidence of these plans being implemented. Since AR5 a number of studies, predominantly from Europe and 28 North America, have investigated the extent to which adaptation has been integrated into conservation 29 planning and is being implemented at site and regional scale (Macgregor and van Dijk, 2014; Delach et al., 30 2019; Prober et al., 2019; Clifford et al., 2020; Barr et al., 2021; Duffield et al., 2021). A common pattern in 31 these studies is that vulnerability has been assessed and potential adaptation actions identified, but 32 implementation has been limited beyond actions to improve ecological condition, which may increase 33 resilience at a local scale. | 246 - 246 | 'rot-Adapt-Mitig-Impa( | | |
| IPCC_AR6_WGII _Full_Report | Hermoso et al. (2016); Thieme et al. (2016); Abell et al. (2017); Brooks et al. (2018) Increase habitat patch size site and expand protected areas Limited evidence High agreement Generally increase resilience because of functioning natural processes, large species populations and refugial areas Eigenbrod et al. (2015); Oliver et al. (2015a) Increase replication and representation of protected areas Limited evidence, High agreement Various benefits inferred, including, wider range of climatic and other conditions, less risk of extreme events affecting many rather than few areas. More sites available for colonisation by range expanding species and better conditions to maintain species in situ under range contraction. | 247 - 247 | 'rot-Adapt-Mitig-Impa( | | |
| IPCC_AR6_WGII _Full_Report | (2012); Patino-Martinez et al. (2012); Thomas et al. (2016) Restoring hydrological processes of wetlands, rivers and catchments, including by raising water tables and restoring original channels of watercourses, Medium evidence, High agreement Wetland restoration is well established as a conservation measure in some countries. Can reduce vulnerability to drought with climate change but evidence to demonstrate effectiveness as an adaptation measure is limited and requires long-term monitoring of a range of sites. Little restoration of degraded tropical peatlands to date Carroll et al. (2011); Hossack et al. (2013); Dokulil (2016); Timpane-Padgham et al. | 247 - 247 | 'rot-Adapt-Mitig-Impa( | | |
| IPCC_AR6_WGII _Full_Report | Christmas et al. (2016) Adjusting conservation strategies and site objectives to reflect changing species distributions and habitat characteristics Robust evidence, High Agreement Conservation management will need to take account of changes that cannot be prevented, for example in the distribution of species and composition of communities, in order to protect and manage biodiversity as effectively as possible in a changing climate. | 248 - 248 | 'rot-Adapt-Mitig-Impa( | | |
| IPCC_AR6_WGII _Full_Report | 28 Within freshwater environments, connectivity of watercourses is essential. Fluvial corridors are necessary to 29 ensure migrating fish population survival, even without climate change; with climate change, connectivity 30 becomes crucial for relatively cold-adapted organisms to migrate upstream to colder areas. Connectivity is 31 also important for the larvae of benthic invertebrates to be able to drift downstream and hence to disperse 32 (Brooks et al., 2018); for adult benthic invertebrates, riparian and terrestrial habitat features can potentially 33 affect dispersal. Connectivity within river and wetland systems for some species can also mediated by more 34 mobile animal species such as fish and birds (Martín-Vélez et al., 2020) Which factors are the most 35 important in either promoting their colonisation of new sites or persisting in situ will differ between species 36 and locations. Some general principle have been recognised and can guide conservation policy and practice 37 (England and RSPB, 2020; Stralberg et al., 2020) but this will often require additional investigation and 38 planning based on understanding individual the niche of specific species. | 249 - 249 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII _Full_Report | 39 40 Managed, translocation by moving species from areas where the climate is becoming unsuitable to places 41 where there persistence under climate change is more likely has been discussed as an adaptation option for 42 many years. So far there have been very few examples of this and it is likely to be a last resort in most cases 43 as in many cases it requires a large investment of resources, the outcome is uncertain and there may be 44 adverse impacts on receiving sites. Nevertheless there are cases where it may be a be a viable option 45 (Stralberg et al., 2019). This is discussed in more detail as a case study in section 2.6.5.1. | 249 - 249 | 'rot-Adapt-Mitig-Impa( | | |

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| --- | --- | --- | --- | --- | --- |
| IPCC_AR6_WGII_Full_Report | 17 18 Protected areas—areas of land set aside for species and habitat protection with legal protection from 19 development or exploitation—have been a cornerstone of nature conservation for many years. Their 20 effectiveness under a changing climate has been the subject of debate and investigation. There is now a large 21 body of evidence demonstrating that colonisations by range shifting species are more likely to occur on 22 protected sites compared to non-protected sites for a wide range of taxa (e.g. Thomas et al., 2012b; 23 Gillingham et al., 2015), including across continents (Pavón-Jordán et al., 2020a). This is probably because 24 by protecting large areas of natural and semi-natural habitats they provide suitable places for colonising 25 species (Hiley et al., 2013) which may not be available in the surrounding landscape. Although the evidence 26 for protected areas being associated with reduced extinctions is weaker, the finding in Gillingham et al. | 250 - 250 | 'rot-Adapt-Mitig-Impa( | | |
| IPCC_AR6_WGII_Full_Report | 27 (2015) that protected sites were associated with reduced extinction rates at low latitudes and elevations is 28 strongly suggestive that they can help species' persistence in the face of climate change. | 250 - 250 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | 49 50 EbA includes a range of different approaches. Examples include restoring coastal and river systems to 51 reduce flood risk and improve water quality and the creation of natural areas within urban areas to reduce 52 temperatures through shading and evaporative cooling. EbA is closely linked with a variety of other concepts 53 such as ecosystem services, natural capital and Disaster Risk Reduction (DRR). EbA was becoming a well- 54 recognised concept at the time of AR5 but implementation was still at an early stage in many cases. Since 55 then pilot studies have been assessed and EbA projects have been initiated around the world. The evidence 56 base continues to grow (Table 2.7) and this has led to increasing confidence in approaches which have been 57 shown to work leading to further expansion in some countries (Table 2.7). However, this is not uniform and ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 2 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 2-112 Total pages: 237 1 there is relatively little synthesis across disciplines and regions (Seddon et al., 2020a). Chausson et al. (2020) 2 used a systematic mapping methodology to characterise 386 published studies. They found that interventions 3 in natural or semi-natural ecosystems ameliorated adverse climate change impacts in 66% of cases, with 4 fewer trade-offs than for more artificial systems such as plantation forest. However, the evidence base has 5 substantial gaps. Most of the evidence has been collected in the Global North and there is a lack of robust, 6 site-specific investigations of the effectiveness of interventions compared to alternatives and of more holistic 7 appraisals accounting for broader social and ecological outcomes. | 250 - 251 | Impact | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 6 7 Specific interventions to protect species from climate change, such as the case of South African 8 penguins(Section 2.6.5.5) and the Tasmanian Wilderness World Heritage Area (Section 2.6.5.8), are rare. | 261 - 261 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | 17 18 Adaptation is widely recognised as important for national conservation policy and is being considered in a 19 variety of countries (Section 2.6.5.2, 2.6.5.3). Adaptation in this strategic context includes decisions about 20 the selection and objectives for protected areas, for example identifying places which can act as refugia. It 21 can also mean recognising where protected areas remains important but will support a changing range of 22 species and ecosystems. This is important for directing resources effectively and ensuring that site 23 management remains appropriate. There are however often major uncertainties and the extent to which there 24 will be a need for more radical measures will depend on success in reducing greenhouse gas emissions 25 globally. A global rise of 1.5–2°C would require relatively incremental adjustments to conservation 26 management in many parts of the world, but a 3–4°C rise would require radical, transformational changes to 27 maintain many species and ecosystem services (Morecroft et al., 2012). | 261 - 261 | 'rot-Adapt-Mitig-Impa( | | |
| IPCC_AR6_WGII_Full_Report | 28 29 Whilst adaptation strategies for conservation are relatively common, at least at an outline level, 30 implementation is slow in most places. This may partly reflect lack of resources for conservation in many 31 parts of the world; however, another barrier is that people often value protected sites in their present form. | 261 - 261 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | 51 52 Individual cases show that assisted migration can be successful. Anich & Ward (2017) extended the 53 geographic breeding range of a rare bird, Kirtland's warbler, Setophaga kirtlandii, by 225km by using song 54 playbacks to attract migrating individuals. Wadgymar (2015) successfully transplanted an annual legume, 55 Chamaecrista fasciculata, to sites beyond its current poleward range limit, while Liu (2012) found that all 56 but one of 20 orchid species survived when transplanted to higher elevations than their current range limits. | 261 - 261 | | INTANBILE | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 57 After introducing two British butterfly species to sites ~65 and ~35 km beyond their poleward range ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 2 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 2-123 Total pages: 237 1 margins, Willis (2009) observed that both introduced populations grew, expanded their ranges and survived 2 for at least 8 years. | 261 - 262 | | | |
| IPCC_AR6_WGII_Full_Report | 3 4 Butterflies have been favoured subjects for assisted migration in response to regional climate warming, since 5 they are easy to move and their range dynamics have been extensively studied. The Chequered Skipper 6 butterfly, Carterocephalus palaemon, became locally extinct in England in the 1970's, in an area not close to 7 either the species' poleward or equatorial range limits. Nonetheless, Maes (2019) consider climate a crucial 8 parameter for re-introduction, using SDMs both for choosing the source population in Belgium and 9 introduction site. | 262 - 262 | | | |
| IPCC_AR6_WGII_Full_Report | 16 fasciculata were more successful when sourced from the most poleward existing sites, while individuals 17 from more equatorial habitats performed poorly even when artificially warmed (Wadgymar et al., 2015). | 262 - 262 | | | |
| IPCC_AR6_WGII_Full_Report | 36 37 (Duffield et al., 2021) found that awareness of the need for adaptation was common amongst nature reserve 38 managers and that they were implementing actions that might building resilience to climate change, such as 39 restoring ecosystem processes and reducing fragmentation. . There is a recognition that it will be necessary 40 to change management objectives of protected sites to adjust to changing circumstances but there was little 41 implementation of such changes (Duffield et al., 2021). The main examples of managing change, was at the 42 coast where rising sea level is causing transitions from terrestrial and freshwater systems to coastal and 43 marine ones. | 262 - 262 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | 37 38 Increasing heat wave frequency and intensity recorded in recent decades presents a second threat (van 39 Wilgen and Wannenburgh, 2016; Van Wilgen et al., 2016; Mbokodo et al., 2020). Nests were historically 40 built in insulated guano burrows, but are now frequently sited on open ground (Kemper et al., 2007; 41 Pichegru et al., 2012; Sherley et al., 2012). High temperatures frequently expose the birds to severe heat 42 stress, causing adults to abandon nests and resulting in mortality of eggs and chicks (Frost et al., 1976; 43 Shannon and Crawford, 1999; Pichegru et al., 2012).Intensifying storm surges and greater wave heights can 44 cause nest flooding (Randall et al., 1986; de Villiers, 2002). | 264 - 264 | | | |
| IPCC_AR6_WGII_Full_Report | 45 46 The African penguin's survival in the wild is dependent on the success of adaptation action. Increasing 47 access to food resources is a management priority (IUCN, 2018). One approach is to reduce fishing pressure 48 immediately around breeding colonies. An experiment excluding fishing around colonies since 2008 has 49 demonstrated positive effects (Pichegru et al., 2010; Pichegru et al., 2012; Sherley et al., 2015; Sherley et al., 50 2018; Campbell et al., 2019b). A second approach is to establish breeding colonies closer to their prey. An 51 ongoing translocation initiative aims to entice birds eastwards to recolonise an extinct breeding colony and 52 potentially to establish a new one (Schwitzer et al., 2013; Sherley et al., 2014; International, 2018). Penguin 53 "look-alikes" or decoys, constructed from rubber and concrete, have been placed at the extinct colony site 54 and, along with call play-backs, give the illusion of an established penguin colony (Morris and Hagen, 55 2018). This approach has not yet proven successful. | 264 - 264 | Prot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGII_Full_Report | 56 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 2 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 2-126 Total pages: 237 1 To promote on-site adaptation to heat extremes and flooding, initiatives are underway to provide cooler 2 nesting sites that also provide storm protection and are sufficiently above the high water level (Extinction, 3 2018; International, 2018). Artificial nest boxes of various designs and constructed from a range of materials 4 have been explored in combination with use of natural vegetation. Some designs have proven successful, 5 increasing breeding success (Kemper et al., 2007; Sherley et al., 2012), but the same designs have had less 6 success at other locations (Pichegru, 2013; Lei et al., 2014). | 264 - 265 | Prot-Adapt-Mitig- | | |

* Reference to climate impacts on heritage, heritage protection, and heritage-related climate adaptation/mitigation
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| Report Title (Year) | Quotation Content | Page(s) | Prot-Adapt-Mitig-Impact* | Intangible** | Indigenous*** |
|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 7 8 Hand-rearing and releasing African penguin chicks, including from eggs, has long proven valuable because 9 moulting parents, being shore-bound, are unable to feed late-hatching chicks. Since 2006, over 7,000- 10 orphaned chicks have been released into the wild as part of the Chick Bolstering Project with a success rate 11 of 77% (Schwitzer et al., 2013; Sherley et al., 2014; Klusener et al., 2018; SANCCOB, 2018). A new project 12 at Boulders Beach aims to use real-time weather station data, within-nest temperatures and known thresholds 13 of penguin heat stress as triggers for implementing a Heat Wave Response Plan. Drawing on well- 14 established chick-rearing facilities and a large body of expertise, this includes removing heat-stressed eggs 15 and birds, hand rearing and/or rehabilitation and release. It is hoped that such birds may be released at the 16 proposed new colony site. | 265 - 265 | | | |
| IPCC_AR6_WGII_Full_Report | 39 40 2.6.5.8 Case Study: Protecting Gondwanan refugia against fire in Tasmania, Australia 41 42 Scale: Local 43 Issue: Protection of rare endemic species 44 45 The Tasmanian Wilderness World Heritage Area (TWWHA) has a high concentration of 'paleo-endemic' 46 plant species restricted to cool, wet climates and fire free environments, but recent wildfires have burnt 47 substantial stands, which are unlikely to recover (Harris et al., 2018b, Bowman et al., 2021, The 2016 48 Tasmanian). The fires led to government inquiries and a fire-fighting review, which have suggested changes 49 to management as that climate change will make such fires more likely in the future (Council, 2016; Press, 50 2016; Council, 2019). | 266 - 266 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | 14 15 The TWWHA Management Plan (2016) emphasises Aboriginal fire management as an important value of 16 the area, along with their knowledge of plants, animals, marine resources, minerals (ochre and rock sources), 17 and their connection with the area as a living and dynamic landscape. Fire management planning aims to 18 protect important sites from fire and ensure that management does not impact Aboriginal cultural values 19 (DPIPWE, 2016). Increasingly, there is an acknowledgment that the cessation of traditional fire uses has led 20 to changes in vegetation and calls to incorporate Aboriginal burning knowledge into fire management of the 21 TWWHA. | 267 - 267 | 'rot-Adapt-Mitig-Impa( | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 22 23 2.6.5.9 Case Study: Bhojtal Lake, Bhopal, India 24 25 Scale: Local 26 Issue: Protection of water resources and biodiversity 27 28 The city of Bhopal, the capital of Madhya Pradesh state in central India, is dependent on Bhojtal, a large 29 man-made lake bordering the city, for its water supply (Everard et al., 2020). It is also an important 30 conservation site with wetlands protected under the Ramsar convention and diverse flora and fauna (WWF, 31 2006). Bhojtal also provides a wide range of other benefits to people, including tourism, recreation, 32 navigation, and subsistence and commercial fisheries, supporting the livelihoods of many families (Verma, 33 2001). | 267 - 267 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | 56 57 Blue Carbon ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 2 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 2-135 Total pages: 237 1 2 Blue Carbon ecosystems (mangroves, saltmarshes and seagrass meadows; see glossary) often have high rates 3 of carbon accumulation and sequestration (Section 3.5.5.5; Macreadie et al., 2019). However, quantification 4 of their overall mitigation value is difficult due to variable production of CH4 and N2O (Adams et al., 2012; 5 Rosentreter et al., 2018; MacLean et al., 2019b), uncertainties regarding the provenance of carbon 6 accumulated (Macreadie et al., 2019), and the release of CO2 by biogenic carbonate formation in seagrass 7 ecosystems (Saderne et al., 2019). Therefore, blue carbon strategies, referring to climate change mitigation 8 and adaptation actions based on conservation and restoration of blue carbon ecosystems, can be effective 9 NbS, with evidence of recovery in carbon stocks following restoration, although their global or regional 10 carbon sequestration potential and net mitigation potential may be limited (medium confidence) (Sections 11 3.6.3.1.6; 13.4.3, AR6 WGI 5.6.2.2.2; Duarte et al., 2020). They can also significantly attenuate wave 12 energy, raise the seafloor thus counteracting sea level rise effects, and buffer storm surges and flooding 13 erosion (high confidence) (Sections 13.2.2; 13.10.2). Additionally, they provide a suite of cultural (for 14 example, tourism, livelihood and well-being for native and local communities), provision (e.g. mangrove 15 woods, edible fish and shellfish) and regulation (e.g. nutrient cycling) services (high confidence) (Section 16 3.5.5.5). These services have motivated the implementation of management and conservation strategies of 17 these ecosystems (Sections 3.6.3.1.6; 13.4.2). Blue carbon strategies are relatively new, with many of them 18 experimental and small scale; therefore there is limited evidence of their long-term effectiveness. There is 19 also limited information on the potential emission of other GHGs from restored blue carbon ecosystems, 20 although reconnecting hydrological flow in mangroves and saltmarsh restoration are effective interventions 21 to reduce CH4 and CO2 (limited evidence, medium agreement) (Kroeger et al., 2017; Al-Haj and Fulweiler, 22 2020). | 273 - 274 | 'rot-Adapt-Mitig-Impa( | INTANBILE | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 34 35 AF significantly improves food security and nutrition by increasing access to healthy, diverse diets and 36 rising incomes for food producers, through increased biodiversity of crops, animals, and landscapes (high 37 confidence) (Garibaldi et al., 2016; D'Annolfo et al., 2017; Isbell et al., 2017; Dainese et al., 2019; Bezner 38 Kerr et al. 2021). Livestock mobility improves the site-specific matching of animals' needs with food 39 availability (Damonte et al., 2019; Mijiddorj et al., 2020; Postigo, 2021), and can generate a form of 40 rewilding that restores lost ecosystem functioning (Gordon et al., 2021). Conservation of crop wild relatives 41 in situ supports genetic diversity in crops for the range of future climate scenarios (Redden et al., 2015). | 275 - 275 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | (2020) Urban Ecosystems Urban forests Moderate to High* Moderate Integrated landscape management. Species richness (including exotics) can be high monoculture of an exotic tree lowers resilience and reduces biodiversity Recreation & aesthetics; stormwater absorption benefits; WGII Chapter 06 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 2 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 2-139 Total pages: 237 heat mitigation, air quality improvements Urban wetlands Moderate* Moderate Integrated landscape management. | 277 - 278 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | Recreation & aesthetics; stormwater absorption; heat mitigation; coastal flood protection WGII Chapter 06 Urban grasslands Moderate* Moderate Integrated landscape management fertilized commercial grass monocultures often require irrigation and are less resilient to droughts than native, mixed grasses and forbs Recreation & aesthetics; stormwater absorption; heat mitigation WGII Chapter 06 Open grasslands & savanna Boreal & Temperate Peatlands High Moderate Blocking drainage channels; Raise water level to natural condition; remove planted trees; revegetation of bare peat; No burns; Increases biodiversity resilience; Reduce flood risk Inappropriate hydrological restoration, e.g., flood surface depth greater than natural depth leading to methane emissions Improved water quality in some conditions. | 278 - 278 | 'rot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGII_Full_Report | All leads to loss of biodiversity, and resilience; soil erosion; water insecurity Improved grazing potential for livestock and dairy production, sustainable wildlife harvests, Increased water security, income from eco�tourism, medicanal plants, fuel wood. | 278 - 278 | | | |

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| Report Title (Year) | Quotation Content | Page(s) | Prot-Adapt-Mitig-Impact* | Intangible** | Indigenous*** |
|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 3 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 3-4 Total pages: 236 1 aquaculture (high confidence) and reduced capacity of habitat-forming species to protect shorelines (high 2 confidence). {WGI AR6 Chapter 9, 3.2.2.1, 3.4.2.1–3.4.2.5, 3.4.2.7, 3.4.2.10, 3.4.2.3, 3.4.3.3.3, 3.5.3} 3 4 At local to regional scales, climate change worsens the impacts on marine life of non-climate 5 anthropogenic drivers, such as habitat degradation, marine pollution, overfishing and overharvesting, 6 nutrient enrichment, and introduction of non-indigenous species (very high confidence). Although 7 impacts of multiple climate and non-climate drivers can be beneficial or neutral to marine life, most are 8 detrimental (high confidence). Warming exacerbates coastal eutrophication and associated hypoxia, causing 9 'dead zones' (very high confidence), which drive severe impacts on coastal and shelf-sea ecosystems (very 10 high confidence), including mass mortalities, habitat reduction and fisheries disruptions (medium 11 confidence). Overfishing exacerbates effects of multiple climate-impact drivers on predators at the top of the 12 marine food chain (medium confidence). Urbanization and associated changes in freshwater and sediment 13 dynamics increase the vulnerability of coastal ecosystems like sandy beaches, saltmarshes and mangrove 14 forests to sea-level rise and changes in wave energy (very high confidence). Although these non-climate 15 drivers confound attribution of impacts to climate change, adaptive, inclusive, and evidence-based 16 management reduces the cumulative pressure on ocean and coastal ecosystems, which will decrease their 17 vulnerability to climate change (high confidence). {3.3, 3.3.3, 3.4.2.4–3.4.2.8, 3.4.3.4, 3.5.3, 3.6.2, Cross- 18 Chapter Box SLR in Chapter 3} 19 20 Climate-driven impacts on ocean and coastal environments have caused measurable changes in 21 specific industries, economic losses, emotional harm, and altered cultural and recreational activities 22 around the world (high confidence). Climate-driven movement of fish stocks is causing commercial, 23 small-scale, artisanal, and recreational fishing activities to shift poleward and diversify harvests (high 24 confidence). Climate change is increasing the geographic spread and risk of marine-borne pathogens like 25 Vibrio sp. (very high confidence), which endanger human health and decrease provisioning and cultural 26 ecosystem services (high confidence). Interacting climatic impact-drivers and non-climate drivers are 27 enhancing movement and bioaccumulation of toxins and contaminants into marine food webs (medium 28 evidence, high agreement), and increasing salinity of coastal waters, aquifers, and soils (very high 29 confidence), which endangers human health (very high confidence). Combined climatic impact-drivers and 30 non-climate drivers also expose densely populated coastal zones to flooding (high confidence) and decrease 31 physical protection of people, property, and culturally important sites (very high confidence). {3.4.2.10, 32 3.5.3, 3.5.5, 3.5.5.3, 3.5.6, Cross-Chapter Box SLR in Chapter 3} 33 34 Projections: vulnerabilities, risks, and impacts 35 36 Ocean conditions are projected to continue diverging from a pre-industrial state (virtually certain), 37 with the magnitude of warming, acidification, deoxygenation, sea-level rise and other climatic impact- 38 drivers depending on the emission scenario (very high confidence), and to increase risk of regional 39 extirpations and global extinctions of marine species (medium confidence). Marine species richness near 40 the equator and in the Arctic is projected to continue declining, even with less than 2°C warming by the end 41 of the century (medium confidence). In the deep | 379 - 381 | Prot-Adapt-Mitig-Impact | | INDG |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 22 Without transformation, global inequities will likely increase between regions (high confidence) and conflicts 23 between jurisdictions may emerge and escalate. {3.5, 3.5.2, 3.5.5.3, 3.6, 3.6.2.1, 3.6.3.1, 3.6.3.2, 3.6.3.3, 24 3.6.4.1, 3.6.4.2, 3.6.5, Cross-Chapter Box SLR in Chapter 3, Cross-Chapter Box ILLNESS in Chapter 2} 25 26 Available adaptation options are unable to offset climate-change impacts on marine ecosystems and 27 the services they provide (high confidence). Adaptation solutions implemented at appropriate scales, 28 when combined with ambitious and urgent mitigation measures, can meaningfully reduce impacts 29 (high confidence). Increasing evidence from implemented adaptations indicates that multi-level governance, 30 early-warning systems for climate-associated marine hazards, seasonal and dynamic forecasts, habitat 31 restoration, ecosystem-based management, climate-adaptive management, and sustainable harvesting tend to 32 be both feasible and effective (high confidence). Marine protected areas, as currently implemented, do not 33 confer resilience against warming and heatwaves (medium confidence) and are not expected to provide 34 substantial protection against climate impacts past 2050 (high confidence). However, marine protected areas 35 can contribute substantially to adaptation and mitigation if they are designed to address climate change, 36 strategically implemented, and well governed (high confidence). Habitat restoration limits climate-change 37 related loss of ecosystem services, including biodiversity, coastal protection, recreational use and tourism 38 (medium confidence), provides mitigation benefits on local to regional scales (e.g., via carbon-storing 'blue 39 carbon' ecosystems) (high confidence), and may safeguard fish stock production in a warmer climate 40 (limited evidence). Ambitious and swift global mitigation offers more adaptation options and pathways to 41 sustain ecosystems and their services (high confidence). {3.4.2, 3.4.3.3, 3.5, 3.5.2, 3.5.3, 3.5.5.4, 3.5.5.5, 42 3.6.2.1, 3.6.2.2, 3.6.2.3, 3.6.3.1, 3.6.3.2, 3.6.3.3, 3.6.5, Figure 3.24, Figure 3.25} 43 44 Nature-based solutions for adaptation of ocean and coastal ecosystems can achieve multiple benefits 45 when well-designed and implemented (high confidence), but their effectiveness declines without 46 ambitious and urgent mitigation (high confidence). Nature-based solutions such as ecosystem-based 47 management, climate-smart conservation approaches (i.e., climate-adaptive fisheries and conservation) and 48 coastal habitat restoration can be cost-effective and generate social, economic and cultural co-benefits, while 49 contributing to the conservation of marine biodiversity and reducing cumulative anthropogenic drivers (high 50 confidence). The effectiveness of nature-based solutions declines with warming; conservation and restoration 51 will alone be insufficient to protect coral reefs beyond 2030 (high confidence) and to protect mangroves 52 beyond the 2040s (high confidence). The multi-dimensionality of climate change impacts and their 53 interactions with other anthropogenic stressors calls for integrated approaches that identify trade-offs and 54 synergies across sectors and scales in space and time to build resilience of ocean and coastal ecosystems and 55 the services they deliver (high confidence). {3.4.2, 3.5.2, 3.5.3, 3.5.5.3, 3.5.5.4, 3.5.5.5, 3.6.2.2, 3.6.3.2, 56 3.6.5, Figure 3.25, Table SM3.6} 57 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 3 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 3-7 Total pages: 236 1 Ocean-focused adaptations, especially those that employ nature-based solutions, address existing 2 inequalities, and incorporate just and inclusive decision-making and implementation processes, 3 support the UN Sustainable Development Goals (SDGs) (high confidence). There are predominantly 4 | 382 - 383 | Prot-Adapt-Mitig-Impac | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 14 15 The ocean sustains life on Earth by providing essential resources and modulating planetary flows of energy 16 and materials. Together, harvests from the ocean and inland waters provide more than 20% of dietary animal 17 protein for more than 3.3 billion people worldwide and livelihoods for about 60 million people (FAO, 18 2020b). The global ocean is centrally involved in sequestering anthropogenic atmospheric CO2 and recycling 19 many elements, and it regulates the global climate system by redistributing heat and water (WGI AR6 20 Chapter 9, Fox-Kemper et al., 2021). The ocean also provides a wealth of aesthetic and cultural resources 21 (Barbier et al., 2011), contains vast biodiversity (Appeltans et al., 2012), supports more animal biomass than 22 on land (Bar-On et al., 2018), and produces at least half the world's photosynthetic oxygen (Field et al., 23 1998). Ecosystem services (Annex II: Glossary) delivered by ocean and coastal ecosystems support 24 humanity by protecting coastlines, providing nutrition and economic opportunities (Figure 3.1, Selig et al., 25 2019), and providing many intangible benefits. Even though ecosystem services and biodiversity underpin 26 human well-being and support climate mitigation and adaptation (Pörtner et al., 2021b), there are also ethical 27 arguments for preserving biodiversity and ecosystem functions regardless of the beneficiary (e.g., Taylor et 28 al., 2020). This chapter assesses the impact of climate change on the full spectrum of ocean and coastal 29 ecosystems, on their services and on related human activities, and it assesses marine-related opportunities 30 within both ecological and social systems to adapt to climate change. | 384 - 384 | Prot-Adapt-Mitig-Impact | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII _Full_Report | 31 32 33 34 Figure 3.1: Estimated relative human dependence on marine ecosystems for coastal protection, nutrition, fisheries 35 economic benefits and overall. Each bar represents an index value that semi-quantitatively integrates the magnitude, 36 vulnerability to loss and substitutability of the benefit. Indices synthesize information on people's consumption of 37 marine protein and nutritional status, gross domestic product, fishing revenues, unemployment, education, governance 38 and coastal characteristics. Overall dependence is the mean of the three index values after standardization from 0–1 39 (Details are found in Table 1 and supplementary material of Selig et al. (2019)). This index does not include the ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 3 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 3-9 Total pages: 236 1 economic benefits from tourism or other ocean industries, and data limitations prevented including artisanal or 2 recreational fisheries or the protective impact of saltmarshes (Selig et al., 2019). Values for reference regions 3 established in the WGI AR6 Atlas (Gutiérrez et al., 2021) were computed as area-weighted means from original 4 country-level data. | 384 - 385 | Prot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGII _Full_Report | 24 25 Detecting changes and attributing them to specific drivers have been especially difficult in ocean and coastal 26 ecosystems because drivers, responses and scales (temporal, spatial, organizational) often overlap and 27 interact (IPCC, 2014c; IPCC, 2014b; Abram et al., 2019; Gissi et al., 2021). In addition, some marine 28 systems have short, heterogeneous, or geographically biased observational records, which exacerbate the 29 interpretation challenge (Beaulieu et al., 2013; Christian, 2014; Huggel et al., 2016; Benway et al., 2019). It 30 is even more challenging to detect and attribute climate impacts on marine-dependent human systems, where 31 culture, governance and society also strongly influence observed outcomes. To assess climate-driven change 32 in natural and social systems robustly, IPCC reports rely on multiple lines of evidence, and the available 33 types of evidence differ depending on the system under study (Section 1.3.2.1, Cross-Working Group Box 34 ATTRIB). Lines of evidence used for ocean and coastal ecosystems for this and previous assessments 35 include observed phenomena, laboratory and field experiments, long-term monitoring, empirical and 36 dynamical model analyses, Indigenous knowledge (IK) and local knowledge (LK), and paleorecords (IPCC, 37 2014c; IPCC, 2014b; IPCC, 2019b). The growing body of climate research for ocean and coastal ecosystems 38 and their services increasingly provides multiple independent lines of evidence whose conclusions support 39 each other, raising the overall confidence in detection and attribution of impacts over time (Section 1.3.2.1, 40 Cross-Working Group Box ATTRIB in Chapter 3). | 386 - 386 | Impact | INTANBILE | INDG |
| IPCC_AR6_WGII _Full_Report | 41 The expected frequency of the current one-in-100-year extreme sea level is projected to increase by a median 42 of 20–30 times across tide-gauge sites by 2050, regardless of emission scenario (medium confidence). In 43 addition, extreme-sea-level frequency may be affected by changes in tropical cyclone climatology (low 44 confidence), wave climatology (low confidence), and tides (high confidence) associated with climate change 45 and sea-level change (WGI AR6 Section 9.6.4.2, Fox-Kemper et al., 2021). | 396 - 396 | | | |
| IPCC_AR6_WGII _Full_Report | 22 23 Detection and attribution of ocean acidification in coastal environments are more difficult than in the open 24 ocean due to larger spatial and temporal variability of carbonate chemistry (Duarte et al., 2013; Laruelle et 25 al., 2017; Torres et al., 2021), and to the influence of other natural acidification drivers such as freshwater 26 and high-nutrient riverine inputs (Cai et al., 2011; Laurent et al., 2017; Fennel et al., 2019; Cai et al., 2020) 27 or anthropogenic acidification drivers (Section 3.1) like atmospherically deposited nitrogen and sulphur 28 (Doney et al., 2007; Hagens et al., 2014). Since AR5, the observing network in coastal oceans has expanded 29 substantially, improving understanding of both the drivers and amplitude of observed variability (Sutton et 30 al., 2016). Recent studies indicate that two more decades of observations may be required before 31 anthropogenic ocean acidification emerges over natural variability in some coastal sites and regions (WGI 32 AR6 Section 5.3.5.2, Sutton et al., 2019; Turk et al., 2019; Canadell et al., 2021). | 399 - 399 | | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 22 23 3.3.3.1 Effects of Multiple Drivers on Primary Producers 24 25 Warming and rising CO2 concentrations enhance growth and/or photosynthetic rates in many species of 26 cyanobacteria, picoeukaryotes, coccolithophores, dinoflagellates and diatoms (high confidence) (Fu et al., 27 2007; Sett et al., 2014; Hoppe et al., 2018a; Wolf et al., 2018; Brandenburg et al., 2019), and the optimum 28 pCO2 for growth and/or primary production shifts upward under warming (medium confidence) (Sett et al., 29 2014; Hoppe et al., 2018a). Warming and ocean acidification appear to jointly favour the proliferation and 30 toxicity of harmful algal bloom (HAB) species (limited evidence, high agreement) (Section 3.5.5.3, Bindoff 31 et al., 2019; Brandenburg et al., 2019; Griffith et al., 2019a; Wells et al., 2020), but a 2021 analysis found no 32 uniform global trend in HABs or their distribution over 1985–2018, once field data were adjusted for 33 regional variations in monitoring effort (Hallegraeff et al., 2021). The predominantly detrimental impacts of 34 ocean acidification on coccolithophores can partly be offset by warming (Seifert et al., 2020), but also be 35 exacerbated, depending on the magnitudes of drivers (D'Amario et al., 2020). For non-calcifying 36 macroalgae, responses are highly species-specific and often indicate synergistic interactions between 37 warming and acidification (Kram et al., 2016; Falkenberg et al., 2018). Ocean acidiffcation poses a large risk 38 for coralline algae that is further amplified by warming (medium confidence) (Section 3.4.2.2, Cornwall et 39 al., 2019). However, temperatures up to 5°C above ambient do not decrease calcification (Cornwall et al., 40 2019), and there is limited evidence that some species have the physiological capacity to resist acidification 41 via pH upregulation at the calcification site (Cornwall et al., 2017a). For seagrass, warming beyond a 42 species' thermal tolerance will limit growth and impact germination, but ocean acidification appears to ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 3 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 3-34 Total pages: 236 1 increase thermal tolerance of some eelgrass species by increasing the photosynthesis-to-respiration ratio 2 (medium confidence) (Egea et al., 2018; Scalpone et al., 2020; Zimmerman, 2021). | 409 - 410 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 44 These investigations could inspire future targeted observational and experimental research to test the validity 45 of model assumptions (Payne et al., 2016; Lotze et al., 2019; Heneghan et al., 2021). The state-of-the-art in 46 such experimental research is presented in Box 3.1. | 415 - 415 | | | |
| IPCC_AR6_WGII_Full_Report | Coral bleaching and mortality will increase in frequency and magnitude over the next decades (very high confidence). Analysis of the Coupled Model Intercomparison Project 5 ensemble projects the loss of coral reefs from most sites globally by 2050 under mid to high rates of warming (very likely). | 418 - 418 | | | |
| IPCC_AR6_WGII_Full_Report | communities will differ in species composition and diversity from present reefs (very high confidence). This will greatly diminish the services they provide to society, such as food provision (high confidence), coastal protection (high confidence) and tourism (medium confidence). | 419 - 419 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | 29 30 In response to the global-scale decline in coral reefs and high future risk, recent literature focuses on finding 31 thermal refuges and identifying uniquely resilient species, populations or reefs for targeted restoration and 32 management (Hoegh-Guldberg et al., 2018b). Reefs exposed to internal waves (Storlazzi et al., 2020), 33 turbidity (Sully and van Woesik, 2020) or warm-season cloudiness (Gonzalez-Espinosa and Donner, 2021) 34 are expected to be less sensitive to thermal stress. Mesophotic reefs (30–150 m) have also been proposed as 35 thermal refugia (Bongaerts et al., 2010), although evidence from recent bleaching events, subsurface 36 temperature records, and species overlap is mixed (Frade et al., 2018; Rocha et al., 2018b; Eakin et al., 2019; 37 Venegas et al., 2019; Wyatt et al., 2020). A study of 2584 reef sites across the Indian and Pacific Oceans 38 estimated that 17% had sufficient cover of framework-building corals to warrant protection, 54% required 39 recovery efforts, and 28% were on a path to net erosion (Darling et al., 2019). There is medium evidence for 40 greater bleaching resistance among reefs subject to temperature variability or frequent heat stress (Barkley et 41 al., 2018; Gintert et al., 2018; Hughes et al., 2018a; Morikawa and Palumbi, 2019), but with trade-offs in 42 terms of diversity and structural complexity (Donner and Carilli, 2019; Magel et al., 2019). There is limited 43 agreement about the persistence of thermal tolerance in response to severe heat stress (Le Nohaïc et al., 44 2017; DeCarlo et al., 2019; Fordyce et al., 2019; Leggat et al., 2019; Schoepf et al., 2020). Recovery and 45 restoration efforts that target heat-resistant coral populations and culture heat-tolerant algal symbionts have 46 the greatest potential of effectiveness under future warming (high confidence) (Box 5.5 in SROCC Chapter 47 5, Bay et al., 2017; Darling and Côté, 2018; Baums et al., 2019; Bindoff et al., 2019; Howells et al., 2021); 48 however, there is low confidence that enhanced thermal tolerance can be sustained over time (Section 49 3.6.3.3.2, Buerger et al., 2020). The effectiveness of active restoration and other specific interventions (e.g., 50 reef shading) are further assessed in Section 3.6.3.3.2. | 420 - 420 | 'rot-Adapt-Mitig-Impa( | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 31 32 3.4.2.4 Estuaries, Deltas and Coastal Lagoons 33 34 Estuaries, deltas and lagoons encounter environmental gradients over small spatial scales, generating diverse 35 habitats that support myriad ecosystem services, including food provision, regulation of erosion, nutrient 36 recycling, carbon sequestration, recreation and tourism, and cultural significance (D'Alelio et al., 2021; 37 Keyes et al., 2021). Although these coastal ecosystems have historically been sensitive to erosion-accretion 38 cycles driven by sea level, drought and storms (high confidence) (Peteet et al., 2018; Wang et al., 2018c; 39 Jones et al., 2019b; Urrego et al., 2019; Hapsari et al., 2020; Zhao et al., 2020b), they were impacted for 40 much of the 20th century primarily by non-climate drivers (very high confidence) (Brown et al., 2018b; 41 Ducrotoy et al., 2019; Elliott et al., 2019; He and Silliman, 2019; Andersen et al., 2020; Newton et al., 2020; 42 Stein et al., 2020). Nevertheless, the influence of climate-impact drivers has become more apparent over 43 recent decades (medium confidence) (Table 3.6). | 425 - 425 | Impact | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | SROCC (Bindoff et al., 2019; Oppenheimer et al., 2019) Coastal ecosystems, including saltmarshes, mangroves, vegetated dunes and sandy beaches, can build vertically and expand laterally in response to SLR, though this capacity varies across sites (high confidence). These ecosystems provide important services that include coastal protection and habitat for diverse biota. However, because of human actions that fragment wetland habitats and Seagrass meadows (high confidence) will face moderate to high risk at temperature above 1.5°C global sea surface warming. | 428 - 428 | ʼrot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | Coastal squeeze is expected to accelerate with sea-level rise (SLR). In many locations, finding sufficient sand to rebuild beaches and dunes artificially will become increasingly difficult and expensive as present supplies near project sites are depleted (high confidence). | 431 - 431 | | | |
| IPCC_AR6_WGII_Full_Report | SROCC (Bindoff et al., 2019) Coastal ecosystems are already impacted by the combination of SLR, other climate-related ocean changes, and adverse effects from human activities on ocean and land (high confidence). Attributing such impacts to SLR, however, remains challenging due to the influence of other climate-related and non-climate drivers such as infrastructure development and human�induced habitat degradation (high confidence). Coastal ecosystems, including saltmarshes, mangroves, vegetated dunes and sandy beaches, can build vertically and expand laterally in response to SLR, though this capacity varies across sites (high confidence) as a consequence of human actions that fragment wetland habitats and restrict landward migration, coastal ecosystems progressively lose their ability to adapt to climate-induced changes and Sandy beach ecosystems will increasingly be at risk of eroding, reducing the habitable area for dependent organisms (high confidence). | 431 - 431 | ʼrot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | 9 10 11 For beach fauna, emerging evidence links range shifts, increasing representation by warm-affinity species 12 and mass mortalities to ocean warming (limited evidence, high agreement) (McLachlan and Defeo, 2018; 13 Martin et al., 2019). But even amongst the best-studied taxa, such as turtles, vulnerability to warming (high 14 confidence) and SLR (medium confidence) anticipated on the basis of theory (Poloczanska et al., 2009; Saba 15 et al., 2012; Pike, 2013; Laloë et al., 2017; Tilley et al., 2019) yields only a few detected impacts in the field 16 associated mainly with feminisation (female-skewed sex ratios driven by warmer nest temperatures) (Jensen 17 et al., 2018; Colman et al., 2019; Tilley et al., 2019), phenology (Monsinjon et al., 2019), reproductive 18 success (Bladow and Milton, 2019) and inter-nesting period (Valverde-Cantillo et al., 2019). Moreover, 19 although established vulnerabilities imply high projected future risk for turtles (high confidence) (e.g., 20 Almpanidou et al., 2019; Monsinjon et al., 2019; Patrício et al., 2019; Varela et al., 2019; Santidrián Tomillo 21 et al., 2020), many populations remain resilient to change (Fuentes et al., 2019; Valverde-Cantillo et al., 22 2019; Laloë et al., 2020; Lamont et al., 2020), perhaps because variation in sand temperatures at nesting 23 depth among beaches very likely exceeds the magnitude of warming anticipated by 2100, even under RCP8.5 24 (medium confidence) (Bentley et al., 2020a). As expected for a taxon with a long evolutionary history, turtles 25 display natural adaptation, not only by virtue of broad geographic distributions that include natural climate- 26 change refugia (Boissin et al., 2019; Jensen et al., 2019), but also because some initial responses to warming 27 might counteract anticipated impacts. For example, although feminisation poses a significant long-term risk 28 to turtle populations (high confidence), it might contribute to population growth in the near- to mid-term 29 (medium confidence) (Patrício et al., 2019). Resilience to climate change might be further enhanced by range 30 extensions, alterations in nesting phenology, and fine-scale nest-site selection (medium confidence) (Abella 31 Perez et al., 2016; Santos et al., 2017; Almpanidou et al., 2018; Rivas et al., 2019; Laloë et al., 2020). | 433 - 433 | ʼrot-Adapt-Mitig-Impa | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 8 These SES are largely landlocked and are thus heavily influenced by surrounding landscapes, local and 9 global climate-impact drivers, as well as non-climate drivers (Section 3.1), making them highly vulnerable to 10 cumulative threats. Key climate-impact drivers in SES are warming, increasing frequency and duration of 11 MHWs, acidification, and the increasing in size and number of OMZs (Figure 3.12, Hoegh-Guldberg et al., 12 2014). In AR5, SES were recognised as regionally significant for fisheries and tourism, but highly exposed 13 to both local and global stressors, offering limited options for organisms to migrate in response to climate 14 change (Table 3.10). | 434 - 434 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 13 14 Similar to other coastal ecosystems, evidence since SROCC (Table 3.11) suggests shelf-sea ecosystems and 15 the fisheries and aquaculture they support are sensitive to the interactive effects of climate-impact drivers, as 16 well as non-climate drivers, including nutrient pollution, sedimentation, fishing pressure and resource 17 extraction (Table 3.12, Figure 3.12). Changes in freshwater, nutrient and sediment inputs from rivers due to 18 both climate and non-climate drivers can influence productivity and nutrient limitation, ecosystem structure, 19 carbon export and species diversity and abundance (Balch et al., 2012; Picado et al., 2014), and can result in 20 reduced water clarity and light penetration (Dupont and Aksnes, 2013; McGovern et al., 2019). Seasonal 21 bottom-water hypoxia occurs in some shelf seas (e.g., northern Gulf of Mexico, Bohai Sea, East China Sea) 22 due to riverine inputs of freshwater and nutrients, promoting stratification, enhanced primary production, and 23 organic carbon export to bottom waters (high confidence) (Zhao et al., 2017; Wei et al., 2019; Del Giudice et 24 al., 2020; Große et al., 2020; Jarvis et al., 2020; Rabalais and Baustian, 2020; Song et al., 2020a; Xiong et 25 al., 2020; Zhang et al., 2020a). | 436 - 436 | Impact | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | (Hall, 2002) 5 6 7 Key risks to shelf seas include shifts or declines in marine micro- and macro-organism abundance and 8 diversity driven by eutrophication, HABs and extreme events (storms and MHWs), and consequent effects 9 on fisheries, resource extraction, transportation, tourism and marine renewable energy (Figure 3.12). The 10 combined effects of deoxygenation and warming can affect the metabolism, growth, feeding behaviour and 11 mobility of fish species (Section 3.3.3). The increasing availability of observations mean that ecosystem 12 changes in shelf seas can be increasingly attributed to climate change (high confidence) (Liang et al., 2018; 13 Maharaj et al., 2018; Ma et al., 2019; Meyer and Kröncke, 2019; Bargahi et al., 2020; Bedford et al., 2020; 14 Friedland et al., 2020b; Mérillet et al., 2020). Eutrophication and seasonal bottom-water hypoxia in some 15 shelf seas have been linked to warming (high confidence) (Wei et al., 2019; Del Giudice et al., 2020) and 16 increased riverine nutrient loading (high confidence) (Wei et al., 2019; Del Giudice et al., 2020). Since 17 SROCC, some severe HABs have been attributed to extreme events, such as MHWs (Section 14.4.2, Roberts 18 et al., 2019; Trainer et al., 2019). However, a recent worldwide assessment of HABs attributed the increase 19 in observed HABs to intensified monitoring associated with increased aquaculture production (high 20 confidence) (Hallegraeff et al., 2021). | 437 - 437 | Impact | | |
| IPCC_AR6_WGII_Full_Report | Given the high sensitivity of the coupled human-natural EBUS to oceanographic changes, the future sustainable delivery of key ecosystem services from EBUS is at risk under climate change; those that are most at risk in the 21st century include fisheries (high confidence), aquaculture (medium confidence), coastal tourism (low confidence) and climate regulation (low confidence). | 440 - 440 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 10 11 Despite low confidence in detailed projections for ecological changes in EBUS, the WGI assessment (WGI 12 AR6 Chapter 9, Fox-Kemper et al., 2021) that upwelling-favourable winds will weaken (or be present for 13 shorter durations) at low latitude but intensify at high latitude (high confidence), albeit by no more than 20% 14 in either case (medium confidence), presents some key risks to associated EBUS ecosystems. These include 15 potential decreases in provisioning services, including fisheries and marine aquaculture (Bertrand et al., 16 2018; Kifani et al., 2018; Lluch-Cota et al., 2018; van der Lingen and Hampton, 2018), and cultural services 17 such as nature-based tourism (Section 3.5). | 441 - 441 | Impact | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | The projected effects of climate-induced stressors on polar marine ecosystems present risks for commercial and subsistence fisheries with implications for regional economies, cultures and the global supply of fish, shellfish, and Antarctic krill (high confidence). | 442 - 442 | Impact | | |

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| IPCC_AR6_WGII_Full_Report | 1 2 3 Since SROCC, evidence demonstrates that warmer oceans, less sea ice and increased advection results in 4 increasing primary production in the Arctic, albeit with regional variation (high confidence), while trends 5 remain spatially heterogeneous and less clear in the Antarctic (medium confidence) (Cross-Chapter Paper 6, 6 Del Castillo et al., 2019; Lewis et al., 2020; Pinkerton et al., 2021; Song et al., 2021a). Furthermore, climate 7 warming influences key mechanisms determining energy transfer between trophic levels including: (1) 8 altered size spectra; (2) shifts in trophic pathways; (3) phenological mismatches; and (4) increased top-down 9 trophic regulation (Table 3.15). However, the scale of impacts from changes in these mechanisms on 10 ecosystem productivity in warming polar oceans remains unresolved and is hence assigned low confidence. | 442 - 442 | Impact | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 27 28 Fisheries are largely sustainably managed, yet are expanding polewards following sea-ice melt in the Arctic 29 (high confidence) (Fauchald et al., 2021) and possibly in the Antarctic (limited evidence) (Santa Cruz et al., 30 2018). Tourism is increasing and expanding in both polar regions, while shipping and hydrocarbon 31 exploration are growing in the Arctic, increasing the risks of compound effects on vulnerable and already 32 stressed populations and ecosystems (high confidence) (Sections 3.6.3.1.3, 3.6.3.1.4, Cross-Chapter Paper 6, 33 Hauser et al., 2018; Meredith et al., 2019; Helle et al., 2020; Rogers et al., 2020; Cavanagh et al., 2021). | 444 - 444 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 23 24 The paleo record confirms that marine biodiversity has been vulnerable to climate warming both globally 25 and regionally (very high confidence) (Cross-Chapter Box PALEO in Chapter 1, Stanley, 2016). In extreme 26 cases of warming (e.g., >5.2°C), marine mass extinctions occurred in the geological past, and there may be a 27 relationship between warming magnitude and extinction toll (medium confidence) (Song et al., 2021b). A 28 combination of warming and spreading anoxia caused marine extinctions in ancient episodes of rapid climate 29 warming (high confidence) (Bond and Grasby, 2017; Benton, 2018; Penn et al., 2018; Them et al., 2018; 30 Chen and Xu, 2019). The role of ocean acidification in ancient extinctions is yet to be resolved (low 31 confidence) (Clapham and Payne, 2011; Clarkson et al., 2015; Jurikova et al., 2020; Müller et al., 2020). | 455 - 455 | | | |
| IPCC_AR6_WGII_Full_Report | 9 Similar patterns among marine animals have been described previously for historical warming events (Song 10 et al., 2020b). Tropicalisation is associated with increased representation of herbivorous species (Vergés et 11 al., 2016; Zarco-Perello et al., 2020; Smith et al., 2021), although observations and theory suggest that 12 dietary generalism can also favour range-shifting species (Monaco et al., 2020; Wallingford et al., 2020). | 457 - 457 | | | |
| IPCC_AR6_WGII_Full_Report | Supporting and Regulating Habitat creation and maintenance Status of nesting, feeding, nursery, and mating sites for birds, mammals, and other marine life, and of resting and overwintering places for migratory marine life or insects. Connectivity of ocean habitats. | 475 - 475 | | | |
| IPCC_AR6_WGII_Full_Report | Supporting identities Existence of and access to cultural, heritage, and religious activities, and opportunities for intergenerational knowledge transfer. Sense of place. | 476 - 476 | | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | Ecosystem service and chapter subsection Observed Impacts Projected Impacts All (Section 3.5) Climate change has affected marine "ecosystem services with regionally diverse outcomes, challenging their governance (high confidence). Both positive and negative impacts result for food security through fisheries (medium confidence), local cultures and livelihoods (medium confidence), and tourism and recreation (medium confidence). The impacts on ecosystem services have negative consequences for health and well-being (medium confidence), and for Indigenous Peoples and local communities dependent on fisheries (high confidence) (1.1, 1.5, 3.2.1, 5.4.1, 5.4.2, Figure SPM.2)" (SROCC SPM A.8, IPCC, 2019c). | 477 - 477 | Impact | | INDG |
| IPCC_AR6_WGII_Full_Report | Food provision (Section 3.5.3) "Warming-induced changes in the spatial distribution and abundance of some fish and shellfish stocks have had positive and negative impacts on catches, economic benefits, livelihoods, and local culture (high confidence). There are negative consequences for Indigenous Peoples and local communities that are dependent on fisheries (high confidence). Shifts in species distributions and abundance has challenged international and national ocean and fisheries governance, including in the Arctic, North Atlantic and Pacific, in terms of regulating fishing to secure ecosystem integrity and sharing of resources between fishing entities (high confidence) (3.2.4, 3.5.3, 5.4.2, 5.5.2, Figure SPM.2)". (SROCC SPM A.8.1 IPCC, 2019c). | 477 - 477 | Impact | | INDG |

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| IPCC_AR6_WGII _Full_Report | "[Risks from marine-borne pollutants and pathogens] are projected to be particularly large for human communities with high consumption of seafood, including coastal Indigenous communities (medium confidence), and for economic sectors such as fisheries, aquaculture, and tourism (high confidence) (3.4.3, 5.4.2, Box 5.3)" (SROCC SPM B.8.3, IPCC, 2019c). | 479 - 479 | Impact | | INDG |
| IPCC_AR6_WGII _Full_Report | "Since the early 1980s, the occurrence of harmful algal blooms (HABs) and pathogenic organisms (e.g., Vibrio) has increased in coastal areas in response to warming, deoxygenation and eutrophication, with negative impacts on food provisioning, tourism, the economy and human health (high confidence)." (SROCC Chapter 5 Executive Summary, Bindoff et al., 2019). | 479 - 479 | Impact | | |
| IPCC_AR6_WGII _Full_Report | Cultural Services (Section 3.5.6) "Climate change impacts on marine ecosystems and their services put key cultural dimensions of lives and livelihoods at risk (medium confidence), including through shifts in the distribution or abundance of harvested species and diminished access to fishing or hunting areas. This includes potentially rapid and irreversible loss of culture and local knowledge and Indigenous knowledge, and negative impacts on traditional diets and food security, aesthetic aspects, and marine recreational activities (medium confidence)" (SROCC SPM B.8.4, IPCC, 2019c). | 480 - 480 | Impact | | INDG |
| IPCC_AR6_WGII _Full_Report | 3 Substantial economic losses in the North American Pacific Coast shellfish aquaculture industry in the 2000s 4 assessed in SROCC (Bindoff et al., 2019) and WGII AR5 (Pörtner et al., 2014) remain the clearest example 5 of human harm from ocean acidification. Technology-based adaptations (Section 3.6.3) have minimised 6 aquaculture losses from ocean acidification, including early warning systems to guide hatchery operations 7 and culturing resilient shellfish strains (Section 5.9.4, Barton et al., 2015a). Laboratory studies show that 8 ocean acidification decreases the fitness, growth, or survival of many economically and culturally important 9 larval or juvenile shelled mollusks (high confidence) (Cao et al., 2018; Onitsuka et al., 2018; Stevens and 10 Gobler, 2018; Griffith et al., 2019a; Mellado et al., 2019), and of several valuable wild-harvest crab species 11 (Barton et al., 2015a; Punt et al., 2015; Miller et al., 2016; Swiney et al., 2017; Gravinese et al., 2018; 12 Tomasetti et al., 2018; Long et al., 2019; Trigg et al., 2019). Ocean acidification alters larval settlement and 13 metamorphosis of fish in laboratory studies (high confidence) (Cattano et al., 2018; Espinel-Velasco et al., 14 2018), suggesting possible changes in fish survival and thus fishery characteristics. Deoxygenation can 15 decrease size and abundance of marine species and suppress trophic interactions (Levin, 2003), decrease the 16 diversity within marine ecosystems (Sperling et al., 2016) while temporarily increasing catchability and 17 increasing the risk of overfishing (Breitburg et al., 2018), and decrease the ecosystem services provided by 18 specific fisheries (Orio et al., 2021). The chronic effects of deoxygenation on wild fisheries are complex and 19 highly interactive with co-occurring drivers and overall ecosystem responses (medium evidence, high 20 agreement) (Townhill et al., 2017; Rose et al., 2019). Detecting and attributing marine ecosystem responses 21 to ocean acidification and deoxygenation outside of laboratory studies remains challenging because of the 22 strong influence of co-occurring environmental changes on natural systems (Section 3.3.5, Rose et al., 2019; 23 Doo et al., 2020). | 482 - 482 | Prot-Adapt-Mitig-Impact | INTANBILE | |
| IPCC_AR6_WGII _Full_Report | 3 4 Carbon storage and burial in mangroves, saltmarshes and seagrass meadows (Table Box3.4.1) help regulate 5 ocean and coastal carbon cycling and may contribute to nature-based mitigation, although regional estimates 6 vary widely based on climatic and edaphic conditions (WGIII AR6 Section 7.4). In addition, coastal 7 vegetated ecosystems provide substantial and interdependent regulating, provisioning and cultural ecosystem 8 services. These include disproportionately high biodiversity per unit area (Pörtner et al., 2021a); abundant 9 habitat (Section 3.5.5.1) and nurseries for aquatic, terrestrial, aerial, and microbial species; natural filtration 10 of waste and stormwater runoff into the coastal ocean (Sections 3.5.5.3, 4.2.7, Cross-Chapter Box ILLNESS 11 in Chapter 2); coastal protection (Section 3.5.5.4, Ouyang et al., 2018; Quevedo et al., 2020); food and 12 natural materials (Sections 3.5.3, 3.5.4); and support for tourism, livelihoods, and cultural activities (Section 13 3.5.6). Global estimates of services provided by coastal blue carbon ecosystems depend on the quality of 14 available mapping, which is currently best developed for mangroves (Macreadie et al., 2019), and improving 15 for saltmarshes and seagrasses (McOwen et al., 2017; McKenzie et al., 2020; Young et al., 2021). | 488 - 488 | Prot-Adapt-Mitig- | INTANBILE | |

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| IPCC_AR6_WGII_Full_Report | Mangroves Saltmarshes Seagrass meadows Carbon stocks (MgC ha–1 ) 856 ± 64.2 (79–2208) (Kauffman et al., 2020) 317.2 ± 38.2 (27–1900) (Alongi, 2018c) 139.7 (9.1–628) (Fourqurean et al., 2012; Alongi, 2018d) Carbon burial rate (g C m–2 yr–1 ) 194 ± 30 (6.2–1722) (Wang et al., 2020) 168 ± 14 (1.2–1167.5) (Wang et al., 2020) 220.7 ± 40.2 (-2094–2124) (Alongi, 2018d) Global Carbon burial rate (TgC yr–1 ) 41 (Wang et al., 2020) 12.63 (Wang et al., 2020) 35.31 (Alongi, 2020) Global areal coverage (Mha) 13.7 (Richards et al., 2020) 5.5 (McOwen et al., 2017) 16 (McKenzie et al., 2020) 24 25 26 Coastal vegetated ecosystems are vulnerable to harm from multiple climate and non-climate drivers, and 27 together these have reduced wetland area globally (high confidence) (Section 3.4.2.5) and endangered the 28 services provided by these ecosystems (high confidence). Loss of coastal vegetated ecosystems changes 29 biodiversity (Sections 3.5.2, 3.4.2.3–3.4.2.5) (Numbere, 2019; Parreira et al., 2021), increases risk of damage 30 and erosion from SLR and storms (Sections 3.4.2.3–3.4.2.5, Cross-Chapter Box SLR in Chapter 3, Galeano 31 et al., 2017), and impacts provisioning (Sections 3.5.3–3.5.4, Li et al., 2018b; Maina et al., 2021). These 32 changes also strongly determine the quantity and longevity of blue carbon storage (high confidence) 33 (Macreadie et al., 2019; Lovelock and Reef, 2020). Specific site characteristics and ecosystem responses to 34 climate change will determine future local blue carbon storage or loss (high confidence) (Table Box3.4.2). | 488 - 488 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 22 23 Additional evidence since previous assessments (Table 3.26) confirms that climate-change impacts on ocean 24 and coastal cultural ecosystem services have already disrupted people's place-based emotional attachments 25 and cultural activities (limited evidence, high agreement) (Figure 3.22). Bleaching and mortality of corals in ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 3 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 3-115 Total pages: 236 1 the Great Barrier Reef have induced measurable "reef grief," a type of solastalgia, among reef visitors and 2 researchers (Conroy, 2019; Curnock et al., 2019; Marshall et al., 2019). The mental health of people in 3 Tuvalu (Gibson et al., 2020), Alaska (Allen, 2020), and Honduras (Kent and Brondo, 2020) have suffered 4 from both the experience of climate impacts on ocean and coastal ecosystems (e.g., SLR and changes in 5 fisheries and wildlife), and the anticipation of more in the future. The climate-associated MHWs and harmful 6 algal bloom events in 2014–2016 in the US Pacific Northwest (Moore et al., 2019) prevented seasonal razor 7 clam harvests culturally important to Indigenous Peoples and the local community (Section 3.5.5.3, Crosman 8 et al., 2019). SLR and storm-driven coastal erosion endanger coastal archaeological and heritage sites around 9 the world (very high confidence) (Hoque and Hoque, 2008; Carmichael et al., 2018; Reimann et al., 2018; 10 Elliott and Williams, 2019; Ravanelli et al., 2019; Anzidei et al., 2020; Chemeli et al., 2020; García Sánchez 11 et al., 2020; Harkin et al., 2020; Hil, 2020; Rivera-Collazo, 2020). | 490 - 491 | Impact | | INDG |
| IPCC_AR6_WGII_Full_Report | 25 floating macroalgae from the central Atlantic Ocean and Caribbean Sea, whose proliferation has been 26 attributed to high sea surface temperatures and nutrient enrichment (Wang et al., 2019a), has substantially 27 disrupted beach tourism in the Caribbean and Mexico and imposes millions of dollars of clean-up costs 28 annually on affected beaches (Milledge and Harvey, 2016). | 491 - 491 | | | |
| IPCC_AR6_WGII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 3 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 3-119 Total pages: 236 1 2 3 3.6.2.1 Socio-Institutional Adaptation 4 5 Increasing evidence shows that an effective solution portfolio includes social and institutional adaptation 6 (Figure 3.23, top; Table 3.28). Social adaptation to climate change is already occurring, as people use 7 strategies ranging from accommodating change, to coping, adapting and transforming their livelihoods (Béné 8 and Doyen, 2018; Fedele et al., 2019; Galappaththi et al., 2019; Barnes et al., 2020; Ojea et al., 2020; Green 9 et al., 2021c). Although management and institutions have major roles in adaptation (Gaines et al., 2018; 10 Barange, 2019), marine governance is impeded by increasing numbers of often-competing users and uses 11 (Boyes and Elliott, 2014); sector-led, fragmented, efforts (Nunan et al., 2020); and a legal framework less 12 clear than those on land (Crespo et al., 2019; Guggisberg, 2019). Future social responses depend on warming 13 levels and on the institutional, socio-economic and cultural constructs that allow or limit livelihood changes 14 (medium confidence) (Chapter 18, Galappaththi et al., 2019; Ford et al., 2020; Green et al., 2021c). Both 15 social and institutional transformations are needed to change the structures of power, culture, politics and/or 16 identity associated with marine ecosystems (Section 1.5.2, Wilson et al., 2020b). Ideally, institutional and 17 social adaptation will work together to sustain knowledge systems and education, enhance participation and 18 social inclusion, facilitate livelihood support and transformational change of dependent coastal communities, 19 provide economic and financial instruments, and include polycentric and multi-level governance of 20 transboundary management (Fedele et al., 2019; Fulton et al., 2019). | 494 - 495 | 'rot-Adapt-Mitig-Impa‹ | INTANBILE | |

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| IPCC_AR6_WGII_Full_Report | Livelihood diversification Medium confidence Livelihood diversification in communities dependent on marine and coastal ecosystems reduces climate risks and confers flexibility (Blanchard et al., 2017; Cinner and Barnes, 2019; Mohamed Shaffril et al., 2020; Owen, 2020; Pinsky, 2021; Taylor et al., 2021) Fisheries and mariculture (Section 3.6.3.1.2), coastal communities (Cross�Chapter Box SLR in Chapter 3), tourism (Section 3.6.3.1.3) ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 3 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 3-120 Total pages: 236 to individuals, which is key to adaptive capacity. | 495 - 496 | 'rot-Adapt-Mitig-Impa( | | |
| IPCC_AR6_WGII_Full_Report | (Nurhidayah and McIlgorm, 2019) Climate services (Section 3.6.3.4.3), tourism cruise ship sector (Section 3.6.3.1.3) Multi-level ocean governance High confidence The multi-scale nature of ocean and coastal climate-change risk demands adaptation solutions at multiple levels of governance that consider the objectives and perceptions of all stakeholders to support local implementation of broad strategies. | 496 - 496 | 'rot-Adapt-Mitig-Impa( | | |
| IPCC_AR6_WGII_Full_Report | (Rosendo et al., 2018; Tittensor et al., 2019; Frazão Santos et al., 2020; Rilov et al., 2020; Pinsky et al., 2021) Tourism (Section 3.6.3.1.3), conservation, (Section 3.6.3.2.1.) Sustainable harvesting High confidence Sustainable harvesting is a nature-based solution (NbS) that contributes to adaptation by safeguarding the provision of marine food and cultural services, while reducing the ecological vulnerability of marine ecosystems. | 499 - 499 | Prot-Adapt-Mitig- | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 51 52 53 Sea-level rise (SLR) is already impacting ecosystems, human livelihoods, infrastructure, food security and 54 climate mitigation at the coast and beyond. Ultimately, it threatens the existence of cities and settlements in 55 low lying areas, and some island nations and their cultural heritage (Chapters 9– 15, Cross-Chapter Paper 2 56 and 4 Oppenheimer et al., 2019). The challenge can be addressed by mitigation of climate change and coastal 57 adaptation. | 501 - 501 | 'rot-Adapt-Mitig-Impact | | |
| IPCC_AR6_WGII_Full_Report | 11 12 At centennial timescales, projected SLR represents an existential threat for island nations, low-lying coastal 13 zones, and the communities, infrastructure, and cultural heritage therein (Chapters 9–15, Cross-Chapter 14 Paper 4). Even if climate warming is stabilised at 2°C to 2.5°C GWL, coastlines will continue to reshape 15 over millennia, affecting at least 25 megacities and drowning low-lying areas where 0.6–1.3 billion people 16 lived in 2010 (medium confidence) (WGI AR6 Chapter 9 Marzeion and Levermann, 2014; Clark et al., 2016; 17 Kulp and Strauss, 2019; Fox-Kemper et al., 2021; Strauss et al., 2021). | 503 - 503 | | | |
| IPCC_AR6_WGII_Full_Report | 4 5 Ecosystem-based adaptation can reduce impacts on human settlements and bring substantial co-benefits such 6 as ecosystem services restoration and carbon storage, but they require space for sediment and ecosystems 7 and have site-specific physical limits, at least above 1.5°C GWL (high confidence) (Cross-Chapter Box 8 NATURAL in Chapter 2, Chapters 3, 9, 11, 15, Herbert et al., 2015; Brown et al., 2019; Van Coppenolle and 9 Temmerman, 2019; Watanabe et al., 2019; Neijnens et al., 2021). For example, planting and conserving 10 vegetation helps sediment accumulation by dissipating wave energy and reducing impacts of storms, at least 11 at present-day sea levels (high confidence) (Temmerman et al., 2013; Narayan et al., 2016; Romañach et al., 12 2018; Laengner et al., 2019; Leo et al., 2019). Coastal wetlands and ecosystems can be preserved by 13 landward migration (Schuerch et al., 2018; Schuerch et al., 2019) or sediment supply (VanZomeren et al., 14 2018), but they can be seriously damaged by coastal defences designed to protect infrastructure (Chapters 3, 15 13, Cooper et al., 2020b). Sediment nourishment can prevent erosion, but it can also negatively impact beach 16 amenities and ecosystems through ongoing dredging, pumping and deposition of sand and silts (VanZomeren 17 et al., 2018; de Schipper et al., 2021; Harris et al., 2021). | 504 - 504 | 'rot-Adapt-Mitig-Impa( | | |
| IPCC_AR6_WGII_Full_Report | 35 36 3.6.3.1.3 Tourism 37 Coastal areas, coastal infrastructure and beaches, sustaining tourism that contributes significantly to local 38 economies (James et al., 2019; Ruiz-Ramírez et al., 2019), are under threat from development, SLR and 39 increased wave energy during storms and (high confidence) (Sections 3.4.2.6, 3.4.4–3.4.6, 3.5.6, Lithgow et 40 al., 2019; Ruiz-Ramírez et al., 2019). Engineered solutions like seawalls and revetments have traditionally 41 been used to address coastal erosion (Section 3.6.3.1.1), but soft infrastructure approaches, including beach 42 nourishment, submerged breakwaters and groins, and NbS (Section 3.6.2.1), are becoming more common, 43 partly due to demand from the tourism industry (medium confidence) (Pranzini, 2018; Pranzini et al., 2018). | 506 - 506 | | INTANBILE | |

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| --- | --- | --- | --- | --- | --- |
| IPCC_AR6_WGII_Full_Report | 44 45 Elsewhere, interactions between tourism and climate impacts worsen outcomes for coastal and ocean 46 environments (Section 3.6.3.1.4). Climate change is opening up new cruise-ship routes in the Arctic (Sun et 47 al., 2018), increasing number of visitors and associated stressors, such as litter, to previously undisturbed 48 areas (Anfuso et al., 2020; Hovelsrud et al., 2020; Suaria et al., 2020). Risk reduction for cruise-ship tourism 49 includes disaster response management, improved mapping, and passenger codes of conduct ensuring social, 50 cultural and ecological sustainability (Stewart et al., 2015; Dawson et al., 2016). | 506 - 506 | Impact | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 5 6 Unintended consequences of ecotourism, such as detrimental ecological impacts on reefs (Giglio et al., 7 2020), sharks, marine birds (Monti et al., 2018), and whales (Higham et al., 2016; Barra et al., 2020; Hoarau 8 et al., 2020), can be minimised by relying on evidence-based management of associated activities (Blumstein 9 et al., 2017). Public perception of climate change connections to tourism can create obstacles (Meynecke et 10 al., 2017; Atzori et al., 2018) such as deterring long-term investment in SIDS tourism initiatives (Santos- 11 Lacueva et al., 2017), or benefits like inclining tourists to participate in conservation projects (Curnock et al., 12 2019; Miller et al., 2020b; Ziegler et al., 2021). Social and cultural networks may decrease climate 13 vulnerability, as with Indigenous tourism operators in SIDS (Parsons et al., 2018). Tourism-based adaptation 14 can also be improved by equitable access to resources, and recognition and inclusion of all stakeholders 15 during policy planning and implementation. The principles of marine spatial planning (Papageorgiou, 2016) 16 provide for effectively incorporating stakeholders and could inform development of activities to assess 17 climate-associated risks (e.g., Tzoraki et al., 2018; Loehr, 2020). The recent decrease in global tourism due 18 to the COVID-19 pandemic may offer opportunities to transform existing practices to more sustainable 19 approaches (Cross-Chapter Box COVID in Chapter 7, Gössling et al., 2021). | 507 - 507 | Prot-Adapt-Mitig-Impac | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 20 21 3.6.3.1.4 Maritime transport 22 Increased maritime transport and cruise-ship tourism in the Arctic are already impacting local and 23 Indigenous Peoples, revealing conflicts over the uses of the ocean and the governance needed to support 24 local people and a sustainable blue economy (high confidence) (Debortoli et al., 2019; Palma et al., 2019; 25 Berman et al., 2020; Dundas et al., 2020). While shipping and its associated environmental impacts are 26 projected to grow (Palma et al., 2019; Dawson et al., 2020), adaptation efforts are only at the planning stage 27 (Debortoli et al., 2019). Increased Arctic traffic due to ice loss can benefit trade, transportation and tourism 28 (medium confidence), but will also affect Arctic marine ecosystems and livelihoods (high confidence) (Palma 29 et al., 2019; Dawson et al., 2020). Increasing search-and-rescue activities (Ford and Clark, 2019) reveal 30 capacity gaps to support future demands (Ford and Clark, 2019; Palma et al., 2019). The Low-Impact 31 Shipping Corridors initiative has been developed as an adaptation strategy in the Arctic, although with 32 limited inclusion of IK and LK (Dawson et al., 2020). | 507 - 507 | Prot-Adapt-Mitig-Impac | | INDG |
| IPCC_AR6_WGII_Full_Report | 46 47 Models show that a combination of available management approaches (restoration, reducing non-climate 48 drivers) and speculative interventions (enhanced corals, reef shading) can contribute to sustaining some coral 49 reefs beyond 1.5°C of global warming with declining effectiveness beyond 2°C of global warming (medium 50 confidence) (Figure 3.25, WGII Chapter 17). These proposed interventions are also currently theoretical and 51 impractical over large scales; for example, engineered solutions like reef shading are untested and not 52 scalable at the reef level (Condie et al., 2021). Existing projects suggest that restoration and ecological 53 interventions to habitat-forming ecosystems have additional benefits of raising local awareness, promoting 54 tourism, and creating jobs and economic benefits (Fadli et al., 2012; Boström-Einarsson et al., 2020; Hafezi 55 et al., 2021), provided communities are involved in planning, operation and monitoring (Boström-Einarsson 56 et al., 2020). | 511 - 511 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 24 25 3.6.3.3.1 Sociocultural dimensions (culture, ethics, identity, behaviour) 26 Every coastal community values marine ecosystems for more than the material and intangible resources they 27 deliver, or the physical protection they offer (Díaz et al., 2018). Cultural services that provide identity, 28 spiritual and cultural continuity, religious meaning, or options for the future (e.g., genetic or mineral 29 resources, Bindoff et al., 2019), are not substitutable. Furthermore, interactions between climate impacts and 30 existing inequalities can threaten the human rights of already-marginalised peoples by disrupting livelihoods 31 and food security, which further erodes people's social, economic, and cultural rights (Finkbeiner et al., ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 3 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 3-137 Total pages: 236 1 2018). For instance, European colonisation and ongoing development blocked the Cucapá Indigenous 2 People's access and rights to resources in the Colorado River Delta, USA, over the 20th century. Recent 3 reallocation of water rights and fishing access is allowing the Cucapá people to reconstruct their cultural 4 identity (Sangha et al., 2019), but future climate change impacts could reverse the community's recovery of 5 their cultural heritage. Adaptations that consider local needs may help sustain cultural services (Ortíz Liñán 6 and Vázquez Solís, 2021). | 512 - 513 | Prot-Adapt-Mitig-Impac | INTANBILE | INDG |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 7 8 Interactions with oceans are fundamental to the identities of many coastal Indigenous Peoples (Norman, 9 2017) and this influences Indigenous responses to climate hazards and adaptation. Around 30 million 10 Indigenous Peoples live along coasts (Cisneros-Montemayor et al., 2016). Seafood consumption among 11 Indigenous Peoples is much higher than for non-Indigenous populations, and marine species support many 12 cultural, medicinal and traditional activities contributing to public health (Section 3.5.3.1, Kenny et al., 13 2018). Perpetuation of Indigenous cultures depends on protecting marine ecosystems and on adapting to 14 changes in self-led ways (see Section 3.5.6, Sangha et al., 2019) that promote self-determination (von der 15 Porten et al., 2019). Indigenous resurgence, or reinvigorating Indigenous ways of life and traditional 16 management, can include marine resource protection and ocean-sector development founded on culturally 17 appropriate strategies and partnerships, that are consistent with traditional norms and beneficial to local 18 communities (von der Porten et al., 2019). Successful adaptation would simultaneously improve ecosystem 19 health and address current and historical inequities (Bennett, 2018). Examples include practicing traditional 20 resource management, protecting traditional territories, engaging with monitoring, collaborations with non- 21 Indigenous partners, and reinvesting benefits into capacity-building within communities (von der Porten et 22 al., 2019; Equator Initiative, 2020). The legitimacy of different adaptation strategies depends on local and 23 Indigenous Peoples' acceptance, which is based on cultural values (Adger et al., 2017); financial gain cannot 24 compensate for loss of IK or LK (Wilson et al., 2020b). Palau's recent goal of shifting seafood consumption 25 away from reef fishes (Remengesau Jr., 2019) and limiting and closely monitoring the expansion of 26 ecotourism was prompted by the cultural importance of protecting these reefs and associated traditional 27 fisheries for local consumption, a recognition of the importance of tourism, and the hazard of climate change 28 (Wabnitz et al., 2018a). | 513 - 513 | Prot-Adapt-Mitig- | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 38 39 Transparency, coherence between different actors and initiatives, and project monitoring and evaluation 40 enhance success in adapting and achieving SDG14 (Life below water) (Blasiak et al., 2019). Maladaptation 41 (WGII Chapter 16, Magnan et al., 2016), is a common risk of current project-based funding due to the 42 pressure to produce concrete results (medium confidence) (Parsons and Nalau, 2019; Nunn et al., 2020; Nunn 43 et al., 2021). Maladaptation can be avoided through a focus on building adaptive capacity, community-based 44 management, drivers of vulnerability and site-specific measures (low confidence) (Magnan and Duvat, 2018; 45 Piggott-McKellar et al., 2020; Schipper, 2020). More research is needed to identify ways that governance 46 and financing agreements can help overcome financial barriers and socio-cultural constraints to avoid 47 maladaptation in coastal ecosystems (high confidence) (Hinkel et al., 2018; Miller et al., 2018; Piggott- 48 McKellar et al., 2020; Schipper, 2020). | 514 - 514 | 'rot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | 29 Such development could help small nations reliant on imported fuel meet their climate-mitigation goals and 30 decrease risk from global fuel supply dynamics (Millar et al., 2017; Chen et al., 2018a), but progress is 31 limited by lack of investment (Millar et al., 2017; Lee et al., 2020) or equipment (Aderinto and Li, 2018; 32 Rusu and Onea, 2018). Wave-energy installations, possibly co-located with wind turbines(Perez-Collazo et 33 al., 2018), are promising for both low- to middle-income nations and areas with significant island or remote 34 coastal geographies (Lavidas and Venugopal, 2016; Bergillos et al., 2018; Jakimavičius et al., 2018; Kompor 35 et al., 2018; Penalba et al., 2018; Saprykina and Kuznetsov, 2018; Lavidas, 2019). Wave-energy capture may 36 also diminish storm-induced coastal erosion (Abanades et al., 2018; Bergillos et al., 2018). Tidal energy is a 37 relatively new technology (Haslett et al., 2018; Liu et al., 2018; Neill et al., 2018) with limiting siting 38 requirements (Mofor et al., 2013). Ocean renewable energy expansion faces other technological obstacles 39 including lack of implementable or scalable energy-capture devices, access to offshore sites, competing 40 coastal uses, potential environmental impacts, and lack of power-grid infrastructure at the coast (Aderinto 41 and Li, 2018; Neill et al., 2018). | 515 - 515 | 'rot-Adapt-Mitig-Impa | | |

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| IPCC_AR6_WGII_Full_Report | 6 7 Marine adaptation also shows promise for helping support achievement of economic SDGs (medium 8 confidence) (Figure 3.26). Marine NbS could help blue economy frameworks achieve Decent Work and 9 Economic Growth (SDG8) (Lee et al., 2020), by sustainably and equitably incorporating ecosystem-based 10 fisheries management, restoration or conservation (Sections 3.6.3.1.2, 3.6.3.2.1 and 3.6.3.2.2) (Voyer et al., 11 2018; Cisneros-Montemayor et al., 2019; Cohen et al., 2019; Okafor-Yarwood et al., 2020). NbS that involve 12 active restoration or accommodation can contribute to Sustainable Cities and Communities (SDG11) and 13 Infrastructure (SDG9) (Section 3.6.3.1.1). Newly developed marine industries and livelihoods associated 14 with NbS might support attainment of Sustainable Communities (SDG11) (Cisneros-Montemayor et al., 15 2019). Finance and market mechanisms to support disaster relief or ocean ecosystem services, such as blue 16 carbon or food provisioning, and innovations (SDG9) including new technologies like vessel-monitoring 17 systems (Kroodsma et al., 2018), can contribute to Responsible Consumption and Production (SDG12) 18 (Sumaila and Tai, 2020). Blue economy growth that includes sustainable shipping, tourism, renewable ocean 19 energy, and transboundary fisheries management (Pinsky et al., 2018) have the potential to contribute to 20 Economic Development (SDG8), affordable and clean energy (SDG7) (as well as global mitigation efforts, 21 SDG13, (Hoegh-Guldberg et al., 2019b; Duarte et al., 2020)). Participatory approaches and co-management 22 systems (Section 3.6.2.1) in many maritime sectors can contribute to SDG11 and SDG12 while helping align 23 the blue economy and the SDGs (high agreement) (Lee et al., 2020; Okafor-Yarwood et al., 2020). | 517 - 517 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | 19 Ambitious and swift global mitigation offers more adaptation options and pathways to sustain ecosystems 20 and their services (Figure 3.25). Some solutions target both mitigation and adaptation (e.g., blue carbon 21 conservation, Cross-Chapter Box NATURAL in Chapter 2, Box 3.4), and cross-cutting solutions 22 simultaneously support several ocean-related sectors (e.g., area-based measures support fishing, tourism; 23 Section 3.6.3.2.1) or ecosystem functions (e.g., NbS support coastal protection, biodiversity, habitat, etc., 24 Section 3.6.3.2.2, Sala et al., 2021). Combined solutions also leverage a variety of existing policies and 25 governance systems (Section 3.6.4.3, Duarte et al., 2020) to advance climate mitigation and adaptation. Even 26 communities that face the limits of adaptation, like those who must relocate to cope with rising seas 27 (McMichael et al., 2019; Bronen et al., 2020), urgently require solutions that combine scientific projections, 28 IK and LK, cultural and community values, and ways to preserve cultural identity to support planning and 29 implementation of relocation (McMichael and Katonivualiku, 2020). | 519 - 519 | Prot-Adapt-Mitig- | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 4 5 Human communities can also experience tipping points that alter people's relationships with marine 6 ecosystem services. Indigenous Peoples and local communities may be forced to move from a particular 7 location due to sea-level rise, erosion, or loss of marine resources. Current activities that help sustain 8 Indigenous Peoples and their cultures may no longer be possible in the coming decades, and traditional diets 9 or territories may have to be abandoned. These tipping points have implications for physical and mental 10 health of marine-dependent human communities. | 521 - 521 | | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 14 Examples include diversifying income by shifting from fishing to tourism and relocating communities 15 threatened by flooding to other areas to continue their livelihoods. Tipping points are being passed already in 16 coral reefs and polar systems, and more will probably be reached in the near future, given climate-change 17 projections. Nevertheless, the chances of moving beyond additional tipping points in the future will be 18 minimised if we reduce greenhouse gas emissions, and we also act to limit other human impacts on the 19 ocean, such as overfishing and nutrient pollution. | 521 - 521 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 5 6 The projected ecological impacts of MHWs threaten local communities' and Indigenous Peoples' cultures, 7 incomes, fisheries, tourism, and, in the case of coral reefs, shoreline protection from waves. High-resolution 8 forecasts and early-warning systems, currently most advanced for coral reefs, can help people and industries 9 prepare for MHWs and also collect data on their effects. Identifying and protecting locations and habitats 10 with reduced exposure to MHWs is a key scientific endeavour. For example, corals may be protected from 11 MHWs in tidally-stirred waters or in reefs where cooler water upwells from subsurface. Marine protected 12 areas and no-take zones, in addition to terrestrial protection surrounding vulnerable coastal ecosystems, 13 cannot prevent MHWs from occurring. But, depending on the location and adherence by people to 14 restrictions on certain activities, the cumulative effect of other stressors on vulnerable ecosystems can be 15 reduced, potentially helping to enhance the rate of recovery of marine life. | 523 - 523 | Prot-Adapt-Mitig-Impac | | INDG |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 3 4 The global ocean underpins human well-being through the provision of resources that directly and indirectly 5 feed and employ many millions of people. In many regions, climate change is degrading ocean health and 6 altering stocks of marine resources. Together with over-harvesting, climate change is threatening the future 7 of the sustenance provided to Indigenous Peoples, the livelihoods of artisanal fisheries, and marine-based 8 industries including tourism, shipping and transportation. | 524 - 524 | | | INDG |
| IPCC_AR6_WGII_Full_Report | 33 Declines in tourism and real estate values have also been recorded in the United States, France, and England 34 associated with climate-driven harmful algal blooms. | 524 - 524 | | | |
| IPCC_AR6_WGII_Full_Report | 44 45 Jobs, industries and livelihoods which depend on particular species or are tied to the coast can also be at risk 46 to climate change. Species-dependent livelihoods (e.g., a lobster fishery or oyster farm) are vulnerable due to 47 a lack of substitutes if the fished species are declining, biodiversity is reduced, or mariculture is threatened 48 by climate change or ocean acidification. Coastal activities and industries ranging from fishing (e.g., 49 gleaning on a tidal flat) to tourism to shipping and transportation are also vulnerable to sea-level rise and 50 other climate-change impacts on the coastal environment. The ability of coastal systems to protect the 51 shoreline will decline due to sea-level rise and simultaneous degradation of nearshore systems including 52 coral reefs, kelp forests and coastal wetlands. | 524 - 524 | Prot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGII_Full_Report | 53 54 The vulnerability of communities to losses in marine ecosystem services varies within and among 55 communities. Tourists seeking to replace lost cultural services can adapt by engaging in the activity 56 elsewhere. But communities who depend on tourism for income or who have strong cultural identity linked 57 to the ocean have a more difficult time. Furthermore, climate-change impacts exacerbate existing inequalities ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 3 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 3-149 Total pages: 236 1 already experienced by some communities, including Indigenous Peoples, Pacific Island countries and 2 territories, and marginalized peoples, like migrants and women in fisheries and mariculture. These inequities 3 increase the risk to their fundamental human rights by disrupting livelihoods and food security, while leading 4 to loss of social, economic, and cultural rights. These maladaptive outcomes can be avoided by securing 5 tenure and access rights to resources and territories for all people depending on the ocean, and by supporting 6 decision-making processes that are just, participatory and equitable. | 524 - 525 | Prot-Adapt-Mitig-Impac | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 20 Coastal habitats like mangroves or vegetated dunes protect coastal communities from sea-level rise and 21 storm surges, while supporting fisheries, recreational and aesthetic services as well. Seagrasses, coral reefs 22 and kelp forests also provide important benefits that help humans adapt to climate change, including 23 sustainable fishing, recreation and shoreline protection services. By recognizing these services and benefits 24 of the ocean, nature-based solutions can improve the quality and integrity of the marine ecosystems. | 526 - 526 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 3 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 3-151 Total pages: 236 1 2 3 Figure FAQ3.5: Contributions of nature-based solutions in the oceans to the Sustainable Development Goals. The 4 icons in the bottom show the Sustainable Development Goals to which nature-based solutions in the ocean possibly 5 contribute. [Placeholder figure -- authoritative version on FMS] 6 7 8 [END FAQ3.5 HERE] 9 10 11 Acknowledgements 12 We acknowledge the kind contributions of Rita Erven (GEOMAR Helmholtz Centre for Ocean Research 13 Kiel, Germany), Miriam Seifert (Alfred Wegener Institute for Polar and Marine Research, Germany), 14 Sebastian Rokitta (Alfred Wegener Institute for Polar and Marine Research, Germany), Amy Marie 15 Campbell (National Oceanography Centre, Southampton/Centre for Environment, Fisheries and Aquaculture 16 Science, United Kingdom), Mariana Castaneda-Guzman (Virginia Polytechnic Institute and State University, 17 USA), Stephen Goult (Plymouth Marine Laboratory/National Centre for Earth Observation, United 18 Kingdom), Josh Douglas (Plymouth Marine Laboratory, United Kingdom), Carl Reddin (Museum für 19 Naturkunde, Berlin, Germany) and the PML Communications and Graphics Team (Plymouth Marine 20 Laboratory, United Kingdom) who assisted in drafting figures and tables. | 526 - 527 | | | |
| IPCC_AR6_WGII_Full_Report | 59 Anzidei, M. et al., 2020: Sea Level Rise Scenario for 2100 A.D. in the Heritage Site of Pyrgi (Santa Severa, Italy). | 529 - 529 | | | |

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| IPCC_AR6_WGII_Full_Report | 27 28 In summary, global mean soil moisture has slightly decreased, but regional changes vary, with both increases 29 and decreases of 20% or more in some regions (medium confidence). Drying soil moisture trends are more 30 widespread than wetting trends, not only in arid areas but also in humid and transitional areas (medium 31 confidence). Reduced dry-season water availability is driven mainly by increasing transpiration (medium 32 confidence) 33 34 4.2.2 Observed Changes in Cryosphere (Snow, Glaciers, and Permafrost) 35 36 AR5 reported a decrease in snow cover over most of the Northern Hemisphere, decreases in the extent of 37 permafrost and increases in its average temperature, and glacier mass loss in most parts of the world 38 (Jiménez Cisneros et al., 2014). SROCC (IPCC, 2019c) stated with very high or high confidence (a) 39 reduction in seasonal snow cover (snow cover extent decreased by 13.4% per decade for 1967-2018); (b) 40 glacier mass budget of all mountain regions (excluding the Canadian and Russian Arctic, Svalbard, Antarctica, Greenland) was 490±100 kg m-2 yr-1 41 in 2006-2015; (c) warming of permafrost (e.g. permafrost 42 temperatures increased by 0.39°C in the Arctic for 2007-2017). Tourism and recreation activities have been 43 negatively impacted by declining snow cover, glaciers and permafrost in high mountains (medium 44 confidence). | 634 - 634 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 25 26 27 Regional and global decreasing trends in glacier mass loss are about linear until 1990, after which they 28 accelerated, especially in Western Canada, the USA, and Southern Andes (WGMS, 2017). There is a ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 4 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 4-24 Total pages: 213 1 worldwide growth in the number, total area and total volume of glacial lakes by around 50% between 1990 2 to 2018 due to the global increase in glacier melt rate (Shugar et al., 2020). An increase in area, number and 3 volume of glacial lakes can potentially increase risks of GLOFs with significant negative societal impacts 4 (Ikeda et al., 2016). A drop in glacier runoff has happened in the regions where the glaciers have already 5 passed their peak water stage, example, as in Canadian Rocky Mountains, European Alps, tropical Andes, 6 North Caucasus (Bard et al., 2015; Hock et al., 2019b; Rets et al., 2020). There is medium confidence that the 7 accelerated melting of glaciers has negatively impacted glacier-supported irrigation systems worldwide 8 (Buytaert et al., 2017; Nüsser and Schmidt, 2017; Xenarios et al., 2019). Varying impacts on hydropower 9 production (Schaefli et al., 2019) and tourism industry in some places due to cryosphere changes have also 10 been documented (Hoy et al., 2016; Steiger et al., 2019). | 635 - 636 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 40 41 Floods intensify the mixing of floodwater with wastewater and the redistribution of pollutants (Andrade et 42 al., 2018). In addition, contaminated floodwaters pose an immediate health risk through waterborne diseases 43 (Huang et al., 2016b; Paterson et al., 2018; Setty et al., 2018). Wildfires, along with heavy rainfalls and 44 floods, can also affect turbidity, which increases drinking water treatment challenges and has been linked to 45 increases in gastrointestinal illness (de Roos et al., 2017. Droughts reduce river dilution capacities and 46 groundwater levels {Wen, 2017 #2093), increasing the risk of groundwater contamination (Kløve et al., 47 2014). More generally, contaminated water diminishes its aesthetic value, compromising recreational 48 activities, reducing tourism and property values, and creating challenges for management and drinking water 49 treatment (Eves and Wilkinson, 2014; Khan et al., 2015; Walters et al., 2015). | 651 - 651 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 40 41 With 1,308 GW installed capacity in 2019, hydropower became the world's largest single source of 42 renewable energy (IHA, 2020) (also see Figure 6.12, WGIII). While hydropower reduces emissions relative 43 to fossil fuel-based energy production, hydropower reservoirs are being increasingly associated with GHG 44 emissions caused by submergence and later re-emergence of vegetation under reservoirs due to water level 45 fluctuations (Räsänen et al., 2018; Song et al., 2018; Maavara et al., 2020). A recent global study concluded 46 that reservoirs might emit more carbon than they bury, especially in the tropics (Keller et al., 2021) (medium 47 confidence). | 655 - 655 | | INTANBILE | |

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| IPCC_AR6_WGII_Full_Report | 16 17 Case 7. Improved preparedness reduced mortality: Heatwave in Europe, 2019 18 19 In 2019, Europe experienced several record-breaking heatwaves. In June, the first one featured record heat 20 for that time in early summer, with temperatures of 6-10°C above normal over most of France and Germany, 21 northern Spain, northern Italy, Switzerland, Austria, and the Czech Republic (Climate., 2019). The second 22 heatwave also resulted in all-time records for Belgium, Germany, Luxembourg, the Netherlands, and the 23 United Kingdom in July. Attribution studies (Vautard et al., 2020) demonstrated that these would have had 24 extremely small odds in the absence of human-induced climate change or would have been 1.5-3°C colder 25 without human-induced climate change. This study concluded that state-of-the-art climate models 26 underestimate the trends in local heat extremes compared to the observed trend. Since the 2003 heatwave, 27 which resulted in tens of thousands of deaths across Europe, many European countries have adopted 28 heatwave plans, including early warning systems. Therefore, mortality in 2019 was substantially lower than 29 it might have been. Unfortunately, mortality is not registered systematically across Europe, and therefore 30 comprehensive analyses are missing. But even based on the countries that provide the numbers, more 31 specifically France, Belgium and the Netherlands, the European heatwave of 2019 resulted in over 2500 32 deaths (CRED, 2019). Despite their deadliness and the fact that climate change increases the frequency, 33 intensity and duration of heatwaves globally (Perkins-Kirkpatrick and Lewis, 2020) , heatwaves are not 34 consistently reported in many countries (Harrington and Otto, 2020), rendering it currently impossible to 35 estimate climate change impacts on lives and livelihoods comprehensively. | 661 - 661 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 23 24 Temperature changes lead to changes in the distribution patterns of freshwater species. Poleward and up- 25 elevation range shifts due to warming temperatures tend to ultimately lead to reduced range sizes. Freshwater 26 species in the tropics are particularly vulnerable (Jezkova and Wiens, 2016; Sheldon, 2019). Systematic 27 shifts towards higher elevation and upstream were found for 32 stream fish species in France (Comte and 28 Grenouillet, 2013). In North America, for the bull trout (Salvelinus confluentus) a reduction in the number of 29 occupied sites was documented in a watershed in Montana (Eby et al., 2014). Other impacts include 30 disruption of seasonal movements of migratory waterbirds that regularly visit freshwater ecosystems, with 31 adverse impacts on their feeding and breeding (Finlayson et al., 2006; Bussière et al., 2015). Keystone 32 species, such as the beaver (Caster Canadensis) in North America, have been moving into new areas as the 33 vegetation structure has changed in response to higher temperatures enabling shrubs to establish in the Arctic 34 and alpine tundra ecosystems (Jung et al., 2016). Increased occurrence and intensity of algal blooms have 35 occurred due to the interactive effects of thermal extremes and low dissolved oxygen concentrations in water 36 (Griffith and Gobler, 2020) (4.2.7). A global review found that almost 90% of all studies reviewed 37 documented a decline in salmonid populations in North Amercia and Europe, and identified knowledge gaps 38 elsewhere (Myers et al., 2017). Another review (Pecl et al., 2017) found declines in Atlantic salmon in 39 Finland, and poleward shift in coastal fish species, while another review (Scheffers et al., 2016) noted 40 hybridization between freshwater species like invasive rainbow trout (Oncorhynchus mykiss) and native 41 cutthroat trout (O. clarkia). | 664 - 664 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 57 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 4 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 4-55 Total pages: 213 1 Freshwater (including ice and snow) has diverse meanings and symbolic representations, as well as 2 associated practices, management and reciprocal responsibilities for many Indigenous Peoples, local 3 communities and traditional peoples (Cave and McKay, 2016; Craft, 2018; Hansen and Antsanen, 2018; 4 Ngata, 2018; Chiblow 2019; Wilson et al., 2019; Moggridge and Thompson, 2021). Climate-driven 5 hydrological changes are affecting culturally significant terrestrial and freshwater species and ecosystems, 6 particularly for Indigenous Peoples, local communities and traditional peoples in the Arctic, high-mountain 7 areas, and small islands (high confidence). These climate impacts on cultural water uses are influencing 8 travel, hunting, herding, fishing, and gathering practices, which have negative implications for livelihoods, 9 cultural traditions, economies, and self-determination (Table 4.5). | 666 - 667 | Impact | | INDG |
| IPCC_AR6_WGII_Full_Report | 10 11 Some of these losses may be classified as non-economic loss and damage, such as loss of culture and 12 traditions (Thomas and Benjamin, 2018b; McNamara et al., 2021). The vulnerability of these cultural uses to 13 climate change is exacerbated by historical and ongoing processes of colonialism and capitalism, which 14 dispossessed Indigenous Peoples and disrupted culturally significant multi-species relationships (Whyte, 15 2017; Whyte, 2018; Wilson et al., 2019; Whyte, 2020; Rice et al., 2021) (14.4.7.3; 9.13.2.4). Despite these 16 significant structural barriers, there is medium confidence that some Indigenous Peoples, local communities 17 and traditional peoples are adapting to the risks of climate-driven hydrological changes to cultural water uses 18 and practices (4.6.9). | 667 - 667 | Prot-Adapt-Mitig-Impac | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | Rainy summers increase the difficulty of gathering and moving reindeer to round-up sites and limit hay production for supplementary winter feed (13.8.1.2). | 669 - 669 | | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | (Albert et al., 2018); (Norton�Smith et al., 2016) Small Islands iTaukei Sea level rise Flooding, inundation and salt�water intrusion The village of Vunidogola was relocated in response to inundation, storm surges and flooding, which villagers found emotionally and spiritually distressing. Although the village was relocated as a single unit and on customary lands, the shift away from the coast has impacted spiritual relationships, as the ocean is an integral part of village culture (15.6.5). | 669 - 669 | Impact | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | (Charan et al., 2017); (Piggott�McKellar et al., 2019a) ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 4 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 4-58 Total pages: 213 Small Islands iTaukei Sea level rise Coastal erosion; inundation Villagers of Viti Levu reported their grief at the potential loss of their traditions and livelihoods. In addition, they are concerned as to how climate change is affecting their cosmology and cultural traditions and understand possible relocation as another source of cultural loss (15.6.5). | 669 - 670 | | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 28 29 Apart from climate impacts on hydropower production, climate-induced flood loads and reservoir water level 30 change may lead to dam failure under RCP2.6 and RCP4.5 scenarios (Fluixá-Sanmartín et al., 2018; Fluixá- 31 Sanmartín et al., 2019) (medium confidence). For example, the incidence of 100-year floods in the Skagit 32 river basin in the US and peak winter sediments are projected to increase by 49% and 335%, respectively, by 33 2080, necessitating fundamental changes in hydropower plant operation. Nevertheless, some risks, such as 34 floods, will remain unmitigated even with changes in hydropower operation rules (Lee et al., 2016). Overall, 35 impacts of future extreme events on energy infrastructure have been less studied than impacts of gradual 36 changes (Cronin et al., 2018). Furthermore, future hydropower development may also impact areas of high 37 freshwater megafauna in South America, South and East Asia, and in the Balkan region, and sub-catchments 38 with a high share of threatened freshwater species are particularly vulnerable (Zarfl et al., 2019). Therefore, 39 future hydropower dams will need to be sited carefully (Dorber et al., 2020). | 693 - 693 | 'rot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGII_Full_Report | 54 55 4.5.8 Projected Risks to the Cultural Water Uses of Indigenous Peoples, Local Communities and 56 Traditional Peoples 57 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 4 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 4-87 Total pages: 213 1 AR5 found that climate change will threaten cultural practices and values, although the risks vary across 2 societies and over time (medium evidence, high agreement). Furthermore, AR5 concluded that significant 3 changes in the natural resource base on which many cultures depend would directly affect the cultural core, 4 worldviews, cosmologies and symbols of Indigenous cultures (Adger and Pulhin, 2014). SR1.5 concluded 5 with high confidence that limiting global warming to 1.5°C, rather than 2°C, will strongly benefit terrestrial 6 and wetland ecosystems and their services, including the cultural services provided by these ecosystems 7 (Hoegh-Guldberg et al., 2018). SROCC found with high confidence that cultural assets are projected to be 8 negatively affected by future cryospheric and associated hydrological changes (Hock et al., 2019b). | 698 - 699 | Impact | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 9 10 There is high confidence that the cultural water uses of Indigenous Peoples, local communities, and 11 traditional peoples are at risk of climate change-related hydrological change (Table 4.7). Climate-driven 12 variations in streamflow, saltwater intrusion, and projected increases in water temperature will exacerbate 13 declines of culturally important species and lead to variations or depletion of culturally important places and 14 subsistence practices. For example, in New Zealand, the increasing risk of flood events may impact 15 culturally important fish species for Māori (Carter, 2019), while habitat changes may shift the distribution of 16 culturally significant plants (Bond et al., 2019). In Australia, Yuibera and Koinmerburra Traditional Owners 17 fear the saltwater inundation of culturally significant sites and waterholes (Lyons et al., 2019), while the 18 flooding of culturally significant wetlands will negatively affect the Lumbee Tribe (USA) (Emanuel, 2018). | 699 - 699 | Impact | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | (Soriano and Herath, 2020) Australasia Yuibera and Koinmerburra Traditional Owner groups Sea level rise Flooding Culturally important coastal waterholes, wetlands and sites are at risk of saltwater inundation due to rising sea levels. If inundated, traditional owners may not be able to maintain cultural connections to these important sites (11.4.1). | 699 - 699 | Impact | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | Lyons, 2019 #2810} Australasia Māori Increased precipitation Flooding Increasing flood events may negatively impact spawning and fishing sites of the culturally important īnaka (whitebait; Galaxias maculates) in the Waikōuaiti River (11.4.2). | 699 - 699 | Impact | INTANBILE | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | Central and South America Warao Sea level rise Flooding The partial or total inundation of the Orinoco Delta will result in the loss of freshwater wetlands and species, which will produce rapid shifts in the culturally significant lands and resources of the Warao. Among the affected species is the Mauritia palm, on which Warao culture and livelihoods are based. | 700 - 700 | | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | (Vegas�Vilarrúbia et al., 2015) Europe Saami Increased temperatures; changes in precipitation Winter thaw Reindeer herding is culturally important for Saami and provides a means to maintain traditions, language and cultural identity, thus constituting an essential part of Saami physical and mental wellbeing. | 700 - 700 | | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 4 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 4-101 Total pages: 213 1 2 3 In most regions, hybrid adaptation approaches are underway. For example, sustainable urban drainage 4 systems (SUDS) are a common adaptation measure that can reduce flooding and improve stormwater quality 5 while reducing the urban heat island effect (e.g. (Chan et al., 2019; Loiola et al., 2019; Song et al., 2019; 6 Huang et al., 2020; Lin et al., 2020)) (Box 4.6; 12.5.5.3.2; 12.7.1). Municipal, catchment and local 7 community plans to minimise water-related climate risks are another form of adaptation (Stults and Larsen, 8 2018). Plans involve supply augmentation (Chu, 2017; Bekele et al., 2018), as well as floodplain 9 management, land-use planning, stakeholder coordination, and water demand management (Andrew and 10 Sauquet, 2017; Flyen et al., 2018; Robb et al., 2019; Tosun and Leopold, 2019), with some US cities 11 including strategies to address social inequalities that climate change may exacerbate (Chu and Cannon, 12 2021). | 712 - 713 | 'rot-Adapt-Mitig-Impa | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 21 22 Further studies are required to ascertain the effectiveness of adaptation measures implemented since AR5, 23 particularly for the growing populations of informal and peri-urban settlements. For example, in urban 24 Africa, such informal settlements are sites of political contestation as residents resist municipal relocation 25 strategies for flood alleviation (Douglas, 2018). In addition, the growing complexity of challenges facing 26 urban water management, such as climate change, urbanisation and environmental degradation, warrants a 27 transformative shift away from prevailing siloed approaches of water supply, sanitation and drainage to more 28 integrated systems that enhance adaptive capacity (Ma et al., 2015; Franco-Torres et al., 2020). | 713 - 713 | 'rot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | 44 45 There is high confidence that some Indigenous Peoples, local communities, and traditional peoples could and 46 are adapting to climate-driven hydrological changes and their impacts on culturally-significant sites, species, 47 ecosystems, and practices in polar, high mountain and coastal areas, where sufficient funding, decision- 48 making power and resourcing exist (e.g., (Golden et al., 2015; Bunce et al., 2016; Anderson et al., 2018). | 717 - 717 | 'rot-Adapt-Mitig-Impa | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 56 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 4 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 4-106 Total pages: 213 1 There is high confidence that local people are adapting to the cultural impacts of climate-driven glacier 2 retreat and decline in snow cover and ice in polar and high mountain areas. However, there is also high 3 confidence that such adaptation can be detrimental and disrupt local cultures. For example, in the Peruvian 4 Andes, concerns about water availability for ritual purposes has led to restrictions on pilgrims' removal of 5 ice and limiting the size of ritual candles to preserve the glacier (Paerregaard, 2013; Allison, 2015). | 717 - 718 | 'rot-Adapt-Mitig-Impa | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 6 Relatedly, some local people have questioned the cosmological order, and re-oriented their spiritual 7 relationships accordingly (Paerregaard, 2013; Carey et al., 2017). In Siberia (Mustonen, 2015) and northern 8 Finland (Turunen et al., 2016), community-led decisions among herders favour alternative routing, pasture 9 areas, and shifts in nomadic cycles in response to changing flood events and permafrost conditions (Box 10 13.2). However, loss of grazing land and pasture fragmentation pose adaptation limits, and some strategies 11 such as supplementary feeding and new technologies may further affect cultural traditions of herding 12 communities (Risvoll and Hovelsrud, 2016; Jaakkola et al., 2018). | 718 - 718 | Prot-Adapt-Mitig- | INTANBILE | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 16 17 Not all adaptation responses reduce risks, and some may have long term maladaptive outcomes, even if they 18 are beneficial in the short term. Maladaptation often stems from poor planning and implementation of 19 adaptation responses and because of not addressing the root causes of vulnerability (Schipper, 2020; Eriksen 20 et al., 2021). Of the 319 case studies where adaptation response was found to have some beneficial outcomes, around 1/3rd 21 of them also mentioned the possibility of maladaptation. Migration can often have 22 maladaptive outcomes because migration can exacerbate the inherent vulnerabilities of migrants (4.6.8). For 23 example, slum dwellers in cities may earn higher incomes, but their quality of life worsens (Ayeb-Karlsson 24 et al., 2016). In some instances, even wage rates in migration hotspots can remain low due to the high 25 volume of the migrant population (Fenton et al., 2017b); as such, it does not help buffer consumption against 26 rainfall shocks (Gao and Mills, 2018). Migration also has gendered impacts, with girls from migrating 27 families being taken out of school (Gioli et al., 2014) or interrupting children's education overall (Warner 28 and Afifi, 2014). In planned relocation from vulnerable urban slums, relocation sites can be far from job sites 29 and increase social conflicts (Tauhid and Zawani, 2018). | 731 - 731 | Prot-Adapt-Mitig-Impac | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 45 46 Community-led actions and restoration measures are helping to ameliorate climate impacts and provide "safe 47 havens" to affected freshwater species (high confidence). For example, the Skolt Sámi of Finland have 48 introduced adaptation measures to aid survival of culturally-significant Atlantic salmon stocks in the 49 Näätämö watershed. Atlantic salmon had declined as northern pike, which preys on juvenile salmon, 50 expanded its range in response to warmer water temperatures. Indigenous co-management measures included 51 increasing the catch of pike and documenting important sites (such as lost spawning beds) to ensure 52 ecological restoration encourages further habitat and increased salmon reproduction (Pecl et al., 2017; 53 Mustonen and Feodoroff, 2018). | 748 - 748 | Prot-Adapt-Mitig-Impac | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 21 22 In summary, IK and LK are dynamic and have developed over time to adapt to climate and environmental 23 change in culturally specific and place-based ways (high confidence). Ethical co-production between holders 24 of IK and LK and technical knowledge is a key enabling condition for successful adaptation measures and 25 strategies pertaining to water security, as well as other areas (medium evidence, high agreement). Knowledge 26 co-production is a vital and developing approach to the water-related impacts of climate change that 27 recognises the culture, agency and concerns of Indigenous Peoples and local communities. It is critical to 28 developing effective, equitable and meaningful strategies for addressing the water-related impacts of global 29 warming (Cross-Chapter Box INDIG in Chapter 18). | 749 - 749 | Prot-Adapt-Mitig-Impac | INTANBILE | INDG |

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| IPCC_AR6_WGII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 5 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 5-5 Total pages: 286 1 in major food-producing regions (medium confidence). {WGI Section 11.8, 5.2.2, 5.4.1, 5.4.3, 5.5.2, 5.5.3, 2 Cross-Chapter Box MOVING PLATE in Chapter 5 this Chapter, Section 5.12.4} 3 4 Impacts on food availability and nutritional quality will increase the number of people at risk of 5 hunger, malnutrition and diet-related mortality (high confidence). Climate change will increase the 6 number of people at risk of hunger in mid-century, concentrated in Sub-Saharan Africa, South Asia and 7 Central America (high confidence) (e.g. between 8 million under SSP1-6.0 to 80 million people under SSP3-8 6.0). Increased CO2 concentrations will reduce nutrient density in some crops (high confidence). Climate change will increase loss of years of full health3 9 by 10% in 2050 under RCP8.5 due to undernutrition and 10 micronutrient deficiencies (medium evidence, high agreement). {5.2.2, 5.4.2, 5.4.3, 5.12.1.2, 5.12.4; Cross- 11 Chapter Box MOVING PLATE this Chapter} 12 13 Climate change will increasingly expose outdoor workers and animals to heat stress, reducing labour 14 capacity, animal health, and dairy and meat production (high confidence). The number of days with 15 climatically stressful conditions for outdoor workers will increase by up to 250 workdays per year by 16 century's end in some parts of South Asia, tropical sub-Saharan Africa and parts of Central and South 17 America under SSP5-8.5, with negative consequences such as reduced food productivity, higher costs and 18 prices (medium confidence). From early-to end-century, cattle, sheep, goats, pigs and poultry in the low 19 latitudes will face 72-136 additional days per year of extreme stress from high heat and humidity under 20 SSP5-8.5. Meat and milk productivity will be reduced (medium confidence). {5.5.3.4; 5.12.4} 21 22 Climate change will further increase pressures on terrestrial ecosystem services supporting global food 23 systems (high confidence). Climate change will reduce the effectiveness of pollinator agents as species are 24 lost from certain areas, or the coordination of pollinator activity and flower receptiveness is disrupted in 25 some regions (high confidence). Greenhouse gas emissions will negatively impact air, soil, and water quality, 26 exacerbating direct climatic impacts on yields (high confidence). {5.4.3, Box5.3, Box5.4, 5.5.3.4; 5.7.1, 27 5.7.4, 5.10.3} 28 29 Climate change will significantly alter aquatic food provisioning services and water security with 30 regional variances (high confidence). Climate change will reduce marine fisheries and aquaculture 31 productivity, altering the species that will be fished or cultured, and reducing aquaculture habitat in tropical 32 and sub-tropical areas (high confidence).. Global ocean animal biomass will decrease by 5 to 17% under 33 RCP2.6 and 8.5 respectively from 1970 to 2100 with an average decline of 5% for every 1°C of warming, 34 affecting food provisioning, revenue value and distribution, (medium confidence). Global marine aquaculture 35 will decline under warming and acidification from 2020 to 2100, with potential short-term gains for 36 temperate finfish and overall negative impacts on bivalve aquaculture from habitat reduction (50-100% for 37 some countries in the Northern Hemisphere) (medium confidence). Changes in precipitation, sea level, 38 temperature, and extreme climate events will affect food provisioning from inland and coastal aquatic 39 systems (high confidence). Sea-level rise and altered precipitation will increase coastal inundation and water 40 conflicts between water-dependent sectors, such as rice production, direct human use, and hydropower 41 (medium confidence). {5.8.3, 5.9.3, 5.13, Cross-Chapter Box SLR in Chapter 3}. | 829 - 830 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 26 27 The 1.5°C Special Report concluded that climate-related risks to food security will rise under 1.5°C and will 28 increase further under 2°C or higher. Above 1.5°C, currently available adaptation options will be much less 29 effective and site-specific limits to adaptation will be reached for vulnerable regions and sectors. There was 30 high confidence that limiting warming to 1.5°C will result in smaller net reductions in yields of major crops 31 affecting food availability and nutrition, and that rising temperatures will adversely affect livestock via 32 changes in feed quality, fertility, production, spread of diseases and water availability. | 833 - 833 | Prot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGII_Full_Report | Adaptation projections; food security projections; livelihood projections: e.g. GFPM {TREE} FUND 3.8, DICE 2010, IMPACT {FOOD} ( ) Household and village models Use detailed site-specific data to generate rules that describe the current behaviour of stakeholders such as households or villages. | 844 - 844 | Prot-Adapt-Mitig-Impac | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 24 25 5.4.2.2 Inequalities in cropping systems- other crops and regional disparities 26 27 While those working with major crops have benefited from the release of new cultivars, those growing other 28 crops are typically reliant on a heritage cultivars or landraces. While Indigenous knowledge and local 29 smallholder knowledge and practices play an important role in supporting agrobiodiversity which provides 30 genetic diversity resistant to climate-related stresses, a global and national focus in international research, 31 subsidies and support for a few crop species has contributed to an overall decline in agrobiodiversity (FAO, 32 2019e; Song et al., 2019) Similarly, there is a lack of agronomic innovation and research to service 'minor' 33 crops (Moriondo et al., 2015; Manners and van Etten, 2018). Even some high value commodities grown 34 outside high-income countries suffer from imbalances in the focus of available credit, research, and 35 innovation (Section 5.4.4.3; Glover, 2014; Fischer, 2016; Farrell et al., 2018). There is a possibility that a 36 lack of adaptive capacity and policy support will drive these growers to move away from these diverse crops, ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 5 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 5-29 Total pages: 286 1 further reducing the resilience of food systems by increasing risk of crop loss from pests, disease and drought 2 and potential loss of Indigenous or local knowledge (Section 5.13.5, Table Box 5.1.1). In the Andean 3 Altiplano of Bolivia, for example, Indigenous farmers have traditionally managed a diverse set of native 4 crops which are drought and frost-tolerant, using cultural practices of seed selection and exchange, but have 5 faced an increase in pests and diseases and a decline of traditional crops due to climate change related 6 stresses, out-migration and intensification drivers (Meldrum et al., 2018). | 853 - 854 | Prot-Adapt-Mitig-Impact | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 5 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 5-35 Total pages: 286 1 2 Temperature is the primary determinant for vine development. Recent warming trends have advanced 3 flowering, maturity, and harvest (high confidence) (Koufos et al., 2014; Cook and Wolkovich, 2016; Hall et 4 al., 2016; Ruml et al., 2016; van Leeuwen and Destrac-Irvine, 2017; Koufos et al., 2020; Wang et al., 2020b; 5 Wang and Li, 2020), and wine growing regions have expanded outside the normal temperature bounds of 6 locally grown varieties (limited evidence, high agreement) (Kryza et al., 2015; Irimia et al., 2018). Milder 7 winters have affected harvest in ice-wine growing regions (Pickering et al., 2015). Higher temperatures have 8 mixed effects depending on site, but generally decreases grape quality (Barnuud et al., 2014; Morales et al., 9 2014; Sweetman et al., 2014; Kizildeniz et al., 2015; Kizildeniz et al., 2018). Warming increases sugar 10 accumulation and decreases acidity (Leolini et al., 2019). Secondary metabolites are negatively affected 11 (Biasi et al., 2019; Teslić et al., 2019). Developmental phases are projected to proceed faster in response to 12 warming (high confidence) (Fraga et al., 2016a; Fraga et al., 2016b; García de Cortázar-Atauri et al., 2017; 13 Costa et al., 2019; Molitor and Junk, 2019; Sánchez, 2019). However extreme high temperatures may have 14 inhibitory effects on development (Cuccia et al., 2014). | 859 - 860 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 31 32 Suitability responses to warming are region-specific. In regions where low temperature is a limiting factor, 33 warming will enable growers to grow a wider range of varieties and obtain better-quality wines (high 34 confidence) (Fuhrer et al., 2014; Mosedale et al., 2015; Mosedale et al., 2016; Meier et al., 2018; Jobin 35 Poirier et al., 2019; Maciejczak and Mikiciuk, 2019). Subtropical and Mediterranean regions will experience 36 major declines in fruit quality for high-quality wines (high confidence) (Resco et al., 2016; Lazoglou et al., 37 2018; Cardell et al., 2019; Fraga et al., 2019a; Fraga et al., 2019b; Teslić et al., 2019). These changes will 38 also affect wine tourism (Nunes and Loureiro, 2016). | 860 - 860 | | | |
| IPCC_AR6_WGII_Full_Report | 32 33 [END BOX 5.3 HERE] 34 35 36 5.4.3.4 Observed and projected impacts on cultural ecosystem service 37 38 Cultural ecosystem services (CES) are those non-material benefits, such as aesthetic experiences, recreation, 39 spiritual enrichment, social relations, cultural identity, knowledge and other values (Millennium Ecosystem 40 Assessment, 2005), which support physical and mental health and human well-being (Chan et al., 2012; 41 Triguero-Mas et al., 2015). CES in agricultural and wild landscapes include recreational activities, access to 42 wild or cultivated products, and cultural foods, spiritual rituals, heritage and memory dimensions, and 43 aesthetic experiences (Daugstad et al., 2006; Calvet-Mir et al., 2012; Ruoso et al., 2015). Relative to other 44 ecosystem services, CES in agricultural landscapes has had less research (Merlín-Uribe et al., 2012; Milcu et 45 al., 2013; Bernues et al., 2014; Plieninger et al., 2014; van Berkel and Verburg, 2014; Ruoso et al., 2015; 46 Quintas-Soriano et al., 2016). Agricultural heritage is a key aspect of CES and plays an important role in 47 maintaining agrobiodiversity (Hanaček and Rodríguez-Labajos, 2018). | 861 - 861 | Impact | INTANBILE | |

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| IPCC_AR6_WGII _Full_Report | 48 49 Climate change is projected to have negative impacts on Cultural ecosystem services (medium confidence) 50 (Table 5.4). There is limited evidence that climate change has been the main driver affecting CES of 51 agroecosystems confounded by other drivers such as migration and changing farming patterns (Hanaček and 52 Rodríguez-Labajos, 2018; Dhakal and Kattel, 2019). Recent studies observed declines in CES in Alpine 53 pastures and floodplains in Europe in part due to climate change impacts (Probstl-Haider et al., 2016; 54 Schirpke et al., 2019). Another study estimated that the scenic beauty enjoyed by those who visit the 55 vineyards in central Chile will decline by 18-28% by 2050 due to a combination of reduced precipitation, 56 increased temperatures, and natural fire cycles (Martinez-Harms et al., 2017). More research is needed, 57 however, particularly on cultural heritage, spiritually significant places, and in low-income countries. | 861 - 861 | Impact | INTANBILE | |
| IPCC_AR6_WGII _Full_Report | Region CES Climate Change Scenario Projected impacts from climate change References Central Chile, South America Aesthetic experience of scenic beauty in vine-growing region. | 862 - 862 | Impact | | |
| IPCC_AR6_WGII _Full_Report | Participatory scenario analysis estimated reduction in aesthetic experience from scenic beauty by 18-28% by 2050 for RCP 2.6, with greater impacts under RCP 8.5. | 862 - 862 | Impact | | |
| IPCC_AR6_WGII _Full_Report | (2017) Mountainous regions of Austria Cultural and aesthetic experiences in alpine pastures and diverse agricultural landscapes Temperature + 1.5 °C from 2008 to 2040 and 4 precipitation scenarios (High, similar, seasonal shift and Low). | 862 - 862 | | | |
| IPCC_AR6_WGII _Full_Report | Evaristus (2014) Philippines Nature-based tourism in agri�tourism Not specified Risk of typhoon, drought and strong wind, grass fire, heavy rains. Anticipated to increase vulnerability in terms of human health services and energy use in tourism. | 862 - 862 | Impact | | |
| IPCC_AR6_WGII _Full_Report | Asia (southwest China) Maize • PPB done primarily with women farmers, led to 1500 landraces safeguarded, 12 farmer-preferred varieties released and 30 landraces released, bred for improved yield (15-20% increases), drought resistance, taste, market potential and other priority traits (Song et al., 2019). | 867 - 867 | | | |
| IPCC_AR6_WGII _Full_Report | • Studies suggest PPB improved farmer knowledge, income, and access to resilient seeds, and strengthened institutions ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 5 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 5-43 Total pages: 286 such as women-led farmer cooperatives and a Farmer Seed Network of China (Song et al., 2019). | 867 - 868 | | | |
| IPCC_AR6_WGII _Full_Report | • Diversified landscapes can also enhance cultural ecosystem services, by supporting cultural heritage crops, recreational and aesthetic experiences (medium confidence) (Novikova et al., 2017; Martínez-Paz et al., 2019; Alcon et al., 2020). | 869 - 869 | | INTANBILE | |
| IPCC_AR6_WGII _Full_Report | 15 16 5.8.4 Adaptation 17 18 Adaptation options in land and aquatic-based culturing food production systems include both governance 19 actions and changes in the factors of production (Section 5.4.4, 5.5.4, Reverter et al., 2020). In contrast, 20 adaptation options in fisheries are primarily concentrated in the socio-economic dimension, especially 21 governance and management (Brander et al., 2018; Holsman et al., 2019), and given the scale of the 22 problem, there are relatively few intentional, well-documented examples of implemented tactical responses 23 (Bell et al., 2020). | 899 - 899 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII _Full_Report | 20 21 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 5 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 5-83 Total pages: 286 1 2 Figure 5.13: Global and regional aquaculture production a) world wild capture fisheries and aquaculture inland 3 (freshwater and brackish) and marine production from 1950-2018, b) diversity of aquaculture groups cultured in 2016, 4 and c) regional aquaculture share of total fisheries production, and d) global aquaculture species production in 2018 by 5 region and type (freshwater, brackish, or marine) on a logged scale (FAO, 2018c; FAO, 2020c; FAO, 2020d). | 907 - 908 | | | |

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| IPCC_AR6_WGII_Full_Report | 10 11 Observed impacts on inland systems have generally been site and region specific (high confidence) (Hoegh- 12 Guldberg et al., 2018; Sainz et al., 2019; Lebel et al., 2020). Salinity intrusions into freshwater aquaculture 13 systems have changed oxygen and water quality of inland ponds, resulting in mortalities in areas such as 14 India and Bangladesh (medium confidence) (Dubey et al., 2017; Dabbadie et al., 2018). Rapid changes in 15 temperature, precipitation, droughts, floods and erosion have created significant production losses for aquatic 16 farmers in Cambodia, Laos, Myanmar, Thailand, Viet Nam and Ghana (medium confidence) (Asiedu et al., 17 2017; Pongthanapanic et al., 2019; Lebel et al., 2020). Algal blooming and inland lake browning related to 18 warming was found to negatively affect fish biomass (van Dorst et al., 2018). Observed indirect effects of 19 climate change on aquaculture include extreme weather events that damage coastal aquaculture infrastructure 20 or enable flooding, both leading to animal escapees (e.g. fish, shrimp), damaged livelihoods and interactions 21 with wild species (high agreement, medium evidence) (Beveridge et al., 2018b; Dabbadie et al., 2018; Kais 22 and Islam, 2018; Pongthanapanic et al., 2019; Ju et al., 2020). | 909 - 909 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 16 17 5.9.2.1 Gender and other social vulnerability and roles in aquaculture 18 19 There are regional differences in women's roles, responsibilities and involvement in adaptation strategies in 20 the aquaculture sector. Women comprise 14% of the 2018 global aquaculture workforce of 20.5 million 21 (FAO, 2020c), representing up to 42% of the salmon workforce in Chile (Chávez et al., 2019), 22 predominantly in processing roles (Gopal et al., 2020). In the majority of lower-middle-income countries 23 seaweed culture is dominated by women in family-owned businesses as in Zanzibar and the Philippines 24 (Brugere et al., 2020; Ramirez et al., 2020), where women are not always paid directly but contribute to 25 family incomes (high confidence) (Msuya and Hurtado, 2017; Brugere et al., 2020; Ramirez et al., 2020). In 26 India women collect stocking juveniles and assist in pond construction, in Bangladesh women do the same 27 tasks as men and in Ghana women undertake post-harvest fishing activities (Lauria et al., 2018). Women 28 employed in aquaculture cooperatives gained adaptive capacity, which reduced gender inequities (medium 29 confidence) (Farquhar et al., 2018; Gonzal et al., 2019), but lack of financial access for women can create 30 gender inequality at larger commercial scales (Gurung et al., 2016; Call and Sellers, 2019).Women in 31 aquaculture experience competing roles between employment, childcare and home duties (high confidence) 32 (Morgan et al., 2015; Lauria et al., 2018; Chávez et al., 2019; see Cross-Chapter Box GENDER in Chapter 33 18), and differ from men in terms of perceptions of environmental risk, climate change, adaptation 34 behaviour, with limited contributions to decision-making (medium confidence) (Barange and Cochrane, 35 2018). Therefore, effective climate aquaculture adaptation options need to address gender inequality e.g. | 911 - 911 | Prot-Adapt-Mitig-Impac | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 7 8 9 5.9.3.2 Marine aquaculture 10 11 5.9.3.2.1 Finfish culture 12 Global projections of ocean warming, primary productivity and ocean acidification predict suitable habitat 13 expansions and short-term growth benefits for finfish aquaculture for some regions (medium confidence) (see 14 Figure 5.15) until thermal tolerances or productivity constraints are exceeded by 2090 (Beveridge et al., 15 2018b; Dabbadie et al., 2018; Froehlich et al., 2018a; Catalán et al., 2019; Thiault et al., 2019; Falconer et 16 al., 2020a). Sensitivities for marine finfish may be high even under +1.5-2.0°C (medium confidence) 17 (Gattuso et al., 2018), resulting in finfish farms moving northward to maintain productivity (e.g., Arctic 18 (Troell et al., 2017). Downscaled projections of regionally specific tolerances (Klinger et al., 2017) may be 19 particularly useful for management and planning; a 0.5°C rise is predicted for Chilean salmon aquaculture 20 (Soto et al., 2019) and potential projected negative impacts on productivity in Norway by 2029 (limited 21 evidence) (Falconer et al., 2020a). Marine heatwaves are predicted to increase in occurrence, intensity, and 22 persistence under RCP4.5 or RCP8.5 by 2100 (Oliver et al., 2019; Bricknell et al., 2021) with risk partly 23 mitigated by husbandry (medium confidence) (McCoy et al., 2017). Generally, negative impacts are 24 predicted for marine species with residual risk increasing with level of exposure (Sara et al., 2018; Smale et 25 al., 2019), where warming will affect oxygen solubility and reduce salmon culture capacity (limited 26 evidence) (Aksnes et al., 2019, Chapter 3) and combine with increasing incidence of harmful algal blooms 27 (high confidence) resulting in negative impacts for food security and nutrition and health (Oppenheimer et 28 al., 2019; Colombo et al., 2020; Glibert, 2020; Raven et al., 2020). Climate change is predicted to affect the 29 incidence, magnitude and virulence of finfish disease, e.g., Vibriosis (Barber et al., 2016; Mohamad et al., ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 5 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 5-88 Total pages: 286 1 2019a; Mohamad et al., 2019b), but specific host-pathogen-climate relationships are not yet established (high 2 confidence) (Slenning, 2010; Marcogliese, 2016; Montanchez et al., 2019; Bandin and Souto, 2020; 3 Behringer et al., 2020; Filipe et al., 2020; Montanchez and Kaberdin, 2020). Projected climate change will 4 also increase competition for feed ingredients between aquatic and terrestrial animal production systems (see 5 Section 5.13.2.). | 912 - 913 | Prot-Adapt-Mitig-Impac | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 6 7 5.9.3.2.2 Shellfish culture 8 Globally, there is overall high confidence that suitable shellfish aquaculture habitat will decline by 2100 9 under projected warming, ocean acidification and primary productivity changes, with significant negative 10 impacts for some regions and species before 2100 (Table 5.9, Froehlich et al., 2018a; Ghezzo et al., 2018). | 913 - 913 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 25 26 5.9.3.2.3 Aquatic plant culture 27 There is medium confidence that cultivated seaweeds are predicted to suffer habitat loss resulting in 28 population declines and northward shifts (Table 5.11). | 913 - 913 | | | |
| IPCC_AR6_WGII_Full_Report | 29 30 31 Table 5.11: Projected impacts of climate on specific inland, brackish, and marine culture systems and species. | 913 - 913 | Impact | | |
| IPCC_AR6_WGII_Full_Report | (2020) Temperature increase, ocean acidification Ecopath with RCP 8.5 by 2100 (2.8°C warming and pH 7.89) U.S. Marine Shellfish Reduction primary productivity and subsequent bivalve carrying capacity Chapman et al. (2020) Temperature increase, stratification change RCP8.5 by 2088-2099 Spain Marine Mussels Decline in mussel optimal culture conditions of 60% in upper and 30% in deeper waters by 2099 Des et al. | 914 - 914 | | | |
| IPCC_AR6_WGII_Full_Report | 1 2 3 5.9.3.2.4 Societal impacts within the production system 4 Marine aquaculture provides distinct ecosystem services through provisioning (augmenting wild fishery 5 catches), regulating (coastal protection, carbon sequestration, nutrient removal, improved water clarity), 6 habitat and supporting (artificial habitat) and cultural (livelihoods and tourism) services (Gentry et al., 2020), 7 which vary with species, location, and husbandry (Alleway et al., 2019). Projected thermal increases of 8 1.5°C will reduce ecosystem services, further reduced under 2°C warming, with associated increases in 9 acidification, hypoxia, dead zones, flooding, and water restrictions (medium confidence) (Hoegh-Guldberg et 10 al., 2018). Sudden production loses from extreme climate events can exacerbate food security challenges 11 across production sectors, including aquaculture, increasing global hunger (high confidence) (Cottrell et al., 12 2019; Food Security Information Network, 2020). While aquaculture provides positive influences such as 13 food security and livelihoods, there are negative concerns over environmental impacts (including high 14 nutrient loads from sites) and socio-economic conflicts (Alleway et al., 2019; Soto et al., 2019) and adoption 15 of ecosystem approaches are dependent on particular user groups and regions (Gentry et al., 2017; Brugère et 16 al., 2019; Gentry et al., 2020). In coastal Bangladesh projected saline inundation to wetland ecosystem 17 services will result in ecosystem services losses of raw materials and food provisioning, ranging from USD 18 0-20.0 million under RCP2.6 to RCP8.5 scenarios (Mehvar et al., 2019). Mangrove deforestation for shrimp 19 farming in Asia negatively impacts ecosystem services and reduces climate resilience (medium confidence) 20 (Mehvar et al., 2019; Nguyen and Parnell, 2019; Reid et al., 2019; Custódio et al., 2020), while mangrove 21 reforestation efforts may have some effectiveness in recreating important nursery grounds for aquatic species 22 (low confidence) (Gentry et al., 2017; Chiayarak et al., 2019; Hai et al., 2020). Families are highly vulnerable 23 to climate change where nutritional needs are being met by self-production, e.g., Mozambique, Namibia 24 (Villasante et al., 2015), Zambia (Kaminski et al., 2018) and Bangladesh (high confidence) (Pant et al., 25 2014). Climate change will therefore affect multiple ecosystem services where ultimately decisions on 26 balance or trade-offs will vary with regional perceptions of service value (high confidence). | 915 - 915 | Prot-Adapt-Mitig-Impact | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 5 6 7 5.9.4.2 Species selections and selective breeding 8 Adaptation options at the operational level include species selections, e.g., cultivation of brackish species 9 (shrimp, crabs) during dry seasons, and rice-finfish in wetter seasons in Thailand (Chiayarak et al., 2019), 10 use of salt-tolerant plants in Viet Nam (Nhung et al., 2019; Paik et al., 2020), converting inundated rice 11 paddies into aquaculture, rotating shrimp, and rice culture (high confidence) (Chiayarak et al., 2019). Species 12 diversification through co-culture, integrated aquaculture-agriculture (e.g. rice-fish) or integrated multi- 13 trophic culture (e.g. shrimp-tilapia-seaweed or finfish-bivalve-seaweed) may maintain farm long-term 14 performance and viability by: creating new aquaculture opportunities; promoting societal and environmental 15 stability; reducing GHG emissions through reduced feed usage and waste, and; carbon sequestration 16 (medium confidence) ( see Section 5.10, Li et al., 2019; Galappaththi et al., 2020b; Prakoso et al., 2020; Tran 17 et al., 2020) (Ahmed et al., 2017; Bunting et al., 2017; Gasco et al., 2018; Soto et al., 2018; Ahmed et al., 18 2019; Dubois et al., 2019; FAO, 2019c; Freed et al., 2020). In practice, most aquaculture operations 19 concentrate on single-species systems (Metian et al., 2020) and barriers such as land availability, freshwater 20 resources and lack of credit access may limit the uptake and success of integrated adaptation approaches to 21 climate change (Ahmed et al., 2019; Tran et al., 2020; Kais and Islam, 2021). | 917 - 917 | Prot-Adapt-Mitig- | | |

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| IPCC_AR6_WGII_Full_Report | 44 45 5.9.4.3 Farm site selection, infrastructure, and husbandry 46 47 Land-based aquaculture systems including hatcheries may reduce exposure to climatic extremes (due to 48 better control of the culture environment), limit water usage, reduce juvenile reliance and buffer climate 49 effects using optimal diets (high confidence) (Barton et al., 2015; Reid et al., 2019; Cominassi et al., 2020). | 917 - 917 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 55 56 Geographical selection of marine farm sites may prevent climate productivity declines (medium confidence) 57 (Froehlich et al., 2018a; Sainz et al., 2019; Oyinlola et al., 2020), particularly for temperature–related ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 5 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 5-93 Total pages: 286 1 mortality hotspots (Garrabou et al., 2019), harmful algal bloom occurrences (Dabbadie et al., 2018) or 2 extreme events (Liu et al., 2020; Wu et al., 2020). However, while downscaled climate forecasts facilitate 3 localized adaptation planning (Falconer et al., 2020a), such projections are rare (Whitney et al., 2020). GIS 4 can be used for climate adaptive planning along with routine site assessments (Falconer et al., 2020b; 5 Galappaththi et al., 2020b; Jayanthi et al., 2020). Building coastal protection, stronger cages and mooring 6 systems, deeper ponds and using sheltered bays can reduce escapees and mortalities related to flooding, 7 increased storms and extreme events (medium confidence) (Dabbadie et al., 2018; Bricknell et al., 2021; Kais 8 and Islam, 2021). Inshore aquaculture in low-lying areas prone to sea-level salinity intrusion (e.g. Mekong 9 delta and Viet Nam) have already implemented adaptation measures, such as conversion of land to mixed 10 plant-animal systems (Nguyen et al., 2019a), converting freshwater ponds to brackish or saline aquaculture 11 (Galappaththi et al., 2020b), building of dams and dykes (Renaud et al., 2015) and intensification of shrimp 12 or fish pond culture to reduce water and land usage (Nguyen et al., 2019b; Johnson et al., 2020). Other 13 adaptation options for limited water supply are government equitable water allocations and water storage 14 (high confidence) (Bunting et al., 2017; Galappaththi et al., 2020b). | 917 - 918 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | 22 Insurance covers natural disasters and disease, helping to reduce and cope with climate-induced risk, 23 enabling faster livelihood recoveries and preventing poverty (high agreement, limited evidence) (Xinhua et 24 al., 2017; Kalikoski et al., 2018; Soto et al., 2018). For example, small-scale shrimp farmers were willing to 25 pay higher premiums to manage risk, after participation in government pilot insurance schemes, ensuring 26 greater pay-outs if a mortality event occurred (Nyguyen and Pongthanapanic, 2016; Pongthanapanic et al., 27 2019). Technological innovations are more widely implemented in larger operations, with internet access 28 promoting adoption at the farm site (Joffre et al., 2017; Salazar et al., 2018). Improved farm management is a 29 key opportunity (high confidence) to reduce climate risks on aquaculture, where Best Management Practices 30 can increase resiliency (Soto et al., 2018), lower additional risk from non-climatic stressors (Gattuso et al., 31 2018; Smith and Bernard, 2020), and decision-tree frameworks can provide adaptation choices when events 32 occur (Nguyen et al., 2016). | 918 - 918 | 'rot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGII_Full_Report | 33 34 5.9.4.4 Early warning and monitoring systems 35 36 Globally monitoring is increasing to fill scientific uncertainties (Goldsmith et al., 2019), but is not often at 37 spatial scales which facilitate farm or regional adaptation management (Whitney et al., 2020) or data 38 complexities prevent direct uptake by operators, resource managers and policymakers (medium confidence) 39 (Soto et al., 2018; Gallo et al., 2019). Specialized industry portals (Pacific shellfish) and government- 40 established monitoring programs (Chilean salmon) and other observational networks (e.g., GOA-ON) can 41 provide real-time monitoring, early-warning event alerts and facilitate aquaculture decision-making (medium 42 confidence) (Cross et al., 2019; Farcy et al., 2019; Soto et al., 2019; Bresnahan et al., 2020; Peck et al., 2020) 43 (Tilbrook et al., 2019). Seasonal forecasting, downscaled models and early-warning systems provide 44 valuable regional or farm site risk information (Hobday et al., 2018; Galappaththi et al., 2020b; Whitney et 45 al., 2020), but monitoring will need to be useful for farmers, involve farmers, accurate, timely, cost-effective, 46 reviewed and maintained in order to ensure uptake (high confidence) (Soto et al., 2018). Early warning 47 systems for harmful algal blooms enable rapid decision-making and risk mitigation (medium confidence), 48 e.g., ocean colour monitoring in South Africa (Smith and Bernard, 2020), where early harvesting and 49 additional husbandry were used to minimize production and economic losses (Pitcher et al., 2019). New 50 tools, strategies and observations are needed to predict harmful algal bloom occurrences and range shifts 51 with changing climate (high confidence) (Schaefer et al., 2019; Tester et al., 2020), as there is uncertainty on 52 drivers of incidence and toxicity (Wells et al., 2020). | 918 - 918 | 'rot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGII_Full_Report | (2019), Amadou et al. (2020) Increased productivity per unit of land Introduction of multiple species leading to higher land equivalency ratios van Noordwijk et al. (2018), Reppin et al. (2019) Improved biophysical site properties Via limiting soil erosion, facilitating water infiltration, increasing nutrient use efficiency, improving soil physical properties, improving crop nutritional quality, modifying the site micro-climate, and helping to buffer against extreme events Nguyen et al. (2013); Carsan et al. (2014), Rosenstock et al. | 924 - 924 | | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 6 7 8 [START BOX 5.8 HERE] 9 10 Box 5.8: Climate Adaptation and Maladaptation in Cocoa and Coffee Production 11 12 Coffee and cocoa are important crops in low latitude regions where agriculture is projected to be heavily 13 impacted by climate change. Both crops are at risk from climate change impacts by 2050 (Baca et al., 2014; 14 Ovalle-Rivera et al., 2015; Chemura et al., 2016; Schroth et al., 2016; Bacon et al., 2017; Schreyer et al., 15 2018; de Sousa et al., 2019; Lahive et al., 2019; Pham et al., 2019; Cilas and Bastide, 2020). Chocolate and 16 coffee are notable among foods in that their carbon footprint ranges from negative to high, as these industries 17 include both low-input agroforestry systems that have many co-benefits, and high-input monoculture systems 18 where crops are grown without shade, in some cases on sites that have been deforested (Poore and Nemecek, 19 2019). While the coffee industry in many countries has already transitioned from agroforestry to a full-sun 20 production (Jha et al., 2014), the cocoa industry is at a turning point with many growers deciding whether to 21 move to the potentially more productive 'full-sun system', despite a general view that the agroforestry 22 system is more resilient to climate change impacts (Rajab et al., 2016; Schroth et al., 2016; Farrell et al., 23 2018; Niether et al., 2020). | 926 - 926 | Prot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGII_Full_Report | (2019) Loss of habitat, degradation of savannas, native grasslands (grassy biomes) or mangroves wrongly characterized as degraded land suitable for afforestation Right to a healthy environment, right to food Robust evidence, high agreement Veldman et al: (2015), Cormier-Salem and Panfili (2016), Brancalion and Chazdon (2017), Bond et al. (2019), Seddon et al. (2020) Direct negative health impacts; loss of traditional medicine Right to health Limited evidence, medium agreement Dotchamou et al. (2016), Johansson and Isgren (2017) A/R projects affect burial sites as for many communities, the forest is also the resting place for deceased ancestors Right to cultural identity and to main and control their traditional knowledge Limited evidence, high agreement Lyons et al. (2014), Gabriel and Mangahas (2017), Mousseau and Teare (2019) Loss of traditional or Indigenous ecological knowledge and forest management practices Right to cultural identity and traditional knowledge Limited evidence, medium agreement Bayrak and Marafa (2016) Increased labor burden. Benefit sharing by direct cash transfer or in-kind modalities tends to not compensate lost income opportunities. Some projects bring employment opportunities, but these are short term and limited and rarely viable if the opportunity cost of land and labour is considered. Poor farmers may drop out in order to regain access to their land for uses that provide cash returns in the shorter term. | 957 - 957 | Impact | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 9 10 The framing of 'key economic sectors and services' in AR5 focused primarily on three infrastructural areas 11 (energy, water services, transport) and on primary and secondary economic activities (including recreation 12 and tourism, insurance and financial services). Cities, settlements and key infrastructure are also referred to 13 in the IPCC special reports released since AR5. The Special Report on Global Warming of 1.5°C examines 14 impacts of global warming on urban systems and infrastructure in the context of advancing sustainable 15 development and eradicating poverty. It highlights the risks facing residents of unplanned and informal 16 urban settlements, many of which are exposed to a range of climate-related hazards (Sections 3.4.8 and 17 4.4.1.3). The Special Report on Global Warming of 1.5°C also identifies green infrastructure, sustainable 18 land use and planning, and sustainable water management as key adaptation options that can reduce risks in 19 urban areas (SPM C2.4; C. 2.5), and highlights "urban and infrastructure" as one of four system transitions 20 required to limit warming to 1.5°C to create an enabling environment for adaptation (Section 4.3.3). | 1120 - 112 | Prot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGII_Full_Report | 4 5 6.1.4 Global Urban Trends 6 7 Since AR5, many cities and other settlements, particularly unplanned and/or informal in Asia and Africa, 8 have continued to grow at rapid rates (van den Berg , Otto and Fikresilassie 2021). Elsewhere, in Latin 9 America in particular, while growth is less rapid, inequality persists. As a result, cities and settlements are 10 crucial both as sites of potential action on climate change, and sites of increased exposure to risk (medium 11 evidence, high agreement). | 1124 - 112 | Impact | | |

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| IPCC_AR6_WGII_Full_Report | 11 12 As a blueprint for advancing human dignity, the Sustainable Development Goals emphasize the need to 13 consider how to achieve a better and more sustainable future while 'leaving no one behind.' In doing so, they 14 highlight an agenda focused on wellbeing, equality and justice. The objective for SDG11 is defined as: 15 "Make cities and human settlements inclusive, safe, resilient and sustainable" with ten associated targets 16 including ensuring access for all to adequate, safe and affordable housing and basic services; participatory 17 planning; safeguarding heritage features; reducing disasters particularly water related disasters and economic 18 impacts on the poor; and promoting resource efficiency, mitigation and adaptation to climate change, 19 resilience to disasters, and develop and implement plans, in line with the Sendai Framework for Disaster 20 Risk Reduction. Similarly SDG9 aims to build resilient infrastructure, promote inclusive and sustainable 21 industrialization and foster innovation, with associated targets. The IPCC 1.5 special report emphasized that 22 there are often cobenefits in pursuit of SDGs and adaptation strategies where "well-designed mitigation and 23 adaptation responses can support poverty alleviation, food security, healthy ecosystems, equality and other 24 dimensions of sustainable development" (Masson-Delmotte et al., 2018 FAQ 5.1). However there may also 25 be negative trade-offs for example between pursuit of growth and reducing climate change risk (International 26 Council for Science, 2017; Masson-Delmotte et al., 2018 Executive Summary; Roy et al., 2018). | 1129 - 112 | Prot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGII_Full_Report | 13 Shading indicates projected number of days in a year in which conditions of air temperature and humidity surpass a 14 common threshold beyond which climate conditions turned deadly and pose a risk of death (Mora et al., 2017b). Named 15 cities are top fifteen urban areas by population size during 2020, 2050, and 2100 respectively as projected by Hoornweg 16 and Pope (2017) 17 18 19 Locally, the urban heat island also elevates temperatures within cities relative to their surroundings. It is 20 caused by physical changes to the surface energy balance of the pre-urban site from urbanization, resulting 21 from the thermal characteristics and spatial arrangement of the built environment, and anthropogenic heat 22 release ((Oke et al., 2017; Chow et al., 2014; Susca and Pomponi, 2020); WGI FAQ10.1). A considerable 23 body of evidence exists on how the multi-scale impacts and consequent risks arise when local elevated 24 temperatures within settlements are enhanced by climate change, with specific elements of this affecting 25 megacities (Darmanto et al., 2019). The urban heat island itself is amplified during heat waves (Founda and 26 Santamouris, 2017), but the extent to which varies regionally and by time of day (Ward et al., 2016a; Zhao et 27 al., 2018b; Eunice Lo et al., 2020). When combined with warming induced by urban growth, extreme heat ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 6 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 6-23 Total pages: 183 1 risks are expected to affect half of the future urban population, with a particular impact in the tropical Global 2 South and in coastal cities and settlements ((Huang et al., 2019); CCP2.2.2; Table CCP2.A.1). | 1133 - 113 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 24 25 Social surveys from temperate and tropical cities highlight the risk of reduced quality of life during heat 26 events, including increased incidence of personal discomfort in indoor and outdoor settings, elevated anxiety, 27 depression, and other indicators of adverse psychological health, and reductions in physical activity, social 28 interactions, work attendance, tourism, and recreation (high confidence) (Chow et al., 2016; Elnabawi, 29 Hamza and Dudek, 2016; Obradovich and Fowler, 2017; Wang et al., 2017; Wong et al., 2017; Lam, 30 Loughnan and Tapper, 2018; Alves, Duarte and Gonçalves, 2016). Extreme heat may also have a cultural 31 impact, for example affecting major sporting events, with negative impacts on the athletic performance 32 (Brocherie, Girard and Millet, 2015; Casa et al., 2015) and the experience and health of spectators 33 (Hosokawa, Grundstein and Casa, 2018; Kosaka et al., 2018; Matzarakis et al., 2018; Vanos et al., 2019). | 1135 - 113 | Impact | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 35 36 Even where formal planning is the norm, this has often remained oriented toward enabling value adding 37 construction or the protection of existing high value physical assets, e.g., infrastructure and built cultural 38 heritage; private residential) rather than enabling disaster risk reduction for all (Long and Rice, 2019). This 39 tendency has been widely documented, including from cases in Australia, Thailand and Indonesia (King et 40 al., 2016), Canada (Stevens and Senbel, 2017), Amman, Moscow, and Delhi (Jabareen, 2015), and South 41 Africa (Arfvidsson et al., 2017). Such inconsistencies between the delivery of land-use planning and the aims 42 of the Sustainable Development Goals combine with other social structures, economic pathways, and 43 governance systems to shape city risk profiles (Dodman et al., 2017). | 1141 - 114 | Prot-Adapt-Mitig-Impact | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 29 Infrastructure can be broadly understood to include social infrastructure (housing, health, education, 30 livelihoods and social safety nets, security, cultural heritage/institutions, disaster risk management and urban 31 planning), ecological infrastructure (clean air, flood protection, urban agriculture, temperature, green 32 corridors, watercourses and riverways) and physical infrastructure (energy, transport, communications 33 (including digital), built form, water and sanitation and solid waste management) (Thacker et al., 2019). This 34 section focuses especially on physical infrastructure where the literature provides discrete risk and impact 35 assessments. Physical infrastructure systems are often immobile, indivisible, involve high fixed costs, and 36 have longer lifecycles. Social and ecological infrastructure elements are rarely assessed alone and instead 37 tend to be included in wider assessments of event impacts. | 1143 - 114 | 'rot-Adapt-Mitig-Impact | | |
| IPCC_AR6_WGII_Full_Report | 21 22 6.2.4.6 Natural and Ecological Infrastructure 23 24 Urban ecological infrastructure includes green (i.e., vegetated), blue (i.e., water-based), and grey (i.e., non- 25 living) components of urban ecosystems (Li et al., 2017). While land cover change from urbanization 26 directly reduces the extent of natural and ecological infrastructure (e.g. Lin, Meyers and Barnett, 2015), 27 notable risks arise from climate drivers. Recent research particularly highlights future climate impacts on 28 coastal natural infrastructure – including beaches, wetlands, and mangroves – which cause significant 29 economic losses from property damage, decreasing tourism income, as well as loss of natural capital and 30 ecosystem services. Research on climate risks to urban trees and forests is comparatively limited. Instead, 31 urban vegetation and green infrastructure are most often cast as adaptation strategies to reduce urban heat, 32 mitigate drought, and provide other ecosystem benefits (see 6.3.2). | 1149 - 114 | 'rot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | 5 6 Climate risks to urban natural and ecosystem infrastructure entail significant economic costs. For example, in 7 2012, Hurricane Sandy led to total losses of up to US$6.5 million to the New York City region's low-lying 8 salt marshes and beaches (Meixler, 2017). Research from coastal settlements across Catalonia, Spain, shows 9 significant levels of tourism loss (which contribute to 11.1% of the region's GDP), infrastructure damage, 10 and natural capital loss attributed to inundation and erosion of beaches, which are projected to retreat by -0.7 11 meters per year given current sea level rise projections of 0.53 to 1.75 meters by 2100 (Jiménez et al., 2017). | 1150 - 115 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 41 42 Human behaviour can exacerbate climate impacts – for example in the emergence of 'last chance 43 tourism'(Lemieux et al., 2018) focused on built cultural heritage at risk from climate change associated 44 events including from decay or even total loss generated by increased flooding and sea-level rise (Camuffo, 45 Bertolin and Schenal, 2017) and water infiltration from post-flood standing water (Camuffo, 2019). Last 46 chance tourism can lead to increased touristic interest over a short time horizon and to precarious economic 47 conditions, which can lead to further accelerated degradation cultural heritage sites already at-risk from 48 climate change. | 1153 - 115 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 7 8 9 6.3 Adaptation Pathways 10 11 6.3.1 Introduction 12 13 Adaptation pathways are composed of sequences of adaptation actions connected through collaborative 14 learning with the possibility of enabling transformations in urban and infrastructure systems (Werners et al., 15 2021). Individual adaptation actions co-evolve with risks (see Section 6.2) and development processes 16 (Section 6.4) to compose more or less planned adaptation pathways, that can include a range of unanticipated 17 outcomes. This section engages with this complexity by approaching adaptation through the notion of 18 infrastructure. The adaptation options for individual infrastructure systems are reviewed, and in Section 6.4 19 brought together through assessment of cross-cutting enabling conditions. Interpreted broadly, infrastructure 20 includes the social systems, ecological systems and grey/physical systems that underpin safe, satisfying and 21 productive life in the city and beyond (Grimm et al., 2016). Social infrastructure includes housing, health, 22 education, livelihoods and social safety nets, cultural heritage/institutions, disaster risk management and 23 security and urban planning. Ecological infrastructure includes nature-based services: temperature 24 regulation, flood protection and urban agriculture. Grey, or physical infrastructure includes energy, transport, 25 water and sanitation, communications (digital), built form and solid waste management. Framing 26 infrastructure in this way enables an assessment of adaptation that is not constrained to the administrative 27 boundaries of urban settlements, but also includes the flows of material, people and money between urban, 28 peri-urban and more rural places and can include adaptation actions deployed by government, individuals 29 and the private sector. Recognising the complexity of adaptation and the research literature that reaches 30 beyond individual infrastructural domains, the section also reviews urban adaptation through the cross- 31 cutting lenses of equity and mitigation. Section 6.4 assesses the enabling environment (political will, 32 governance, knowledge, finance and social context) that shapes specific adaptation contexts and futures. | 1158 - 115 | 'rot-Adapt-Mitig-Impact | | |

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| Report Title (Year) | Quotation Content | Page(s) | Prot-Adapt-Mitig-Impact* | Intangible** | Indigenous*** |
|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 27 28 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 6 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 6-49 Total pages: 183 1 2 Figure 6.4: The Urban Adaptation Gap. Notes: This is a qualitative assessment presenting individual, non-comparative 3 data for world regions from 25 AR6 CLAs and LAs, the majority from regional chapters. Respondents were asked to 4 make expert summary statements based on the data included within their chapters and across the AR6 report augmented 5 by their expert knowledge. Multiple iterations allowed opportunity for individual and group judgement. Urban 6 populations and risks are very diverse within regions making the presented results indicative only. Variability in data 7 coverage leads to the overall analysis having medium agreement – medium evidence. Major trends identified in 6.3.1 at 8 least meet this level of confidence. Analysis is presented for current observed climate change associated hazards and for 9 three adaptation scenarios: (1) current adaptation (based on current levels of risk management and climate adaptation), 10 (2) planned adaptation (assessing the level of adaptation that could be realised if all national, city and neighbourhood 11 plans and policies were fully enacted), (3) transformative adaptation (if all possible adaptation measures were to be 12 enacted). Assessments were made for the lowest and highest quintile by income. Residual risk levels achieved for each 13 income class under each adaptation scenario are indicated by five adaptation levels: no risk, occasional discomfort, 14 occasional impacts on wellbeing, frequent impacts on wellbeing, extreme events and/or chronic risk. The urban 15 adaptation gap is revealed when levels of achieved adaptation fall short of delivering 'no risk'. The graphic uses IPCC 16 Regions, and has split Asia into two regions: North and East Asia, and Central and South Asia. Technical support is 17 acknowledged from Greg Dodds and Sophie Wang 18 19 20 6.3.3 Adaptation Through Social Infrastructure 21 22 Social infrastructure refers to social, cultural and financial activities and institutions as well as associated 23 property, buildings and artefacts that can be deployed to reduce risk and recover from loss. This section 24 examines land use planning, livelihoods and social protection, emergency and disaster risk management, 25 health systems, education and communication, and cultural heritage. | 1159 - 116 | 'rot-Adapt-Mitig-Impact | | |
| IPCC_AR6_WGII_Full_Report | Multiple programs for differing household needs in Philippines (Bowen et al., 2020) Weather-index insurance in Chinese coastal cities (Rao and Li, 2019); Early warning forecast system and public meteorological service information in Beijing (Song, Zheng and Lin, 2021) Promotive and anticipatory measures; transformational adaptation 7 8 9 Adaptive Social Protection (ASP) may be very good at reducing extreme poverty by helping to meet 10 individual or household needs but not collective needs to mitigate long-term climate shocks. For example, 11 few programmes consider risk assessment and climate-proof infrastructures as anticipatory measures to 12 foster early action and preparedness (Aleksandrova, 2019; Costella et al., 2017). They therefore need to 13 enable the adoption of forward-looking strategies for long-lasting adaptation (Tenzing, 2020). Some 14 examples from China show social protection can improve adaptive capacity of urban communities with 15 social medical insurance, housing subsidies, weather-index insurance, post disaster construction, relocation 16 planning, livelihood shift strategies, and so on (Pan et al., 2015; Zheng et al., 2018b; Rao and Li, 2019; 17 Song, Zheng and Lin, 2021). However, social protection may lead to maladaptation in urban policy when 18 social security, or similar tools (for example insurance) compensate for exposure deincentivise risk reduction 19 (Grove, 2021). In many developing countries, high concentration of poor and vulnerable groups living in 20 disaster-prone zones of urban centres, new urban dwellers and informal residents are often excluded from 21 community-based networks and social services (Aleksandrova, 2019). Risk transfer tools (like insurance) 22 and risk retention measures (like social safety nets) can avoid and minimise the burden of loss and damage 23 and limit secondary and indirect effects (Aleksandrova, 2019; Roberts and Pelling, 2018). | 1163 - 116 | 'rot-Adapt-Mitig-Impa | INTANBILE | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 29 30 6.3.3.6 Cultural heritage/institutions 31 32 The integration of culture into urban policy and planning is increasingly recognised as critical to developing 33 sustainable and resilient cities and features in international agreements such as the SDGs (limited evidence; 34 high agreement) (Sitas, 2020). However, urban cultural policies are still limited, for example, Cape Town is 35 the only African city to have developed a city level cultural policy (Sitas, 2020). Cultural heritage refers to 36 both tangible (e.g. historic buildings and sites) and intangible (e.g. oral traditions and social practices) 37 resources inherited from the past (Fatorić and Egberts, 2020; Jackson, Dugmore and Riede, 2018). Learning 38 about past societal and environment changes through heritage offers opportunity for reflection, transfer of 39 knowledge and skills. This takes place in multiple contexts such as museums and cultural landscapes, and in 40 everyday life (Fatorić and Egberts, 2020; Jackson, Dugmore and Riede, 2018). Cultural heritage is primarily 41 associated with identity and is closely intertwined with the complexities of history, politics, economics and 42 memory. Climate change adds another layer of complexity to cultural heritage and resource management 43 (Fatorić and Seekamp, 2017). Changing climatic conditions are already negatively impacting World Heritage 44 Sites such as the Cordilleras' Rice Terraces of the Philippines and earthen architecture sites - for example the 45 Djenné mosque in Mali are particularly vulnerable to changes in temperature and water interactions 46 (UNESCO, 2021). Climate change impacts intangible cultural heritage across diverse settings such as in the 47 Caribbean and Pacific SIDS where traditional ways of life and related aspects such as oral traditions and 48 performing arts are under threat from extreme weather events (UNESCO, 2021). | 1167 - 116 | Impact | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 49 50 The climate change adaptation options for built cultural heritage fall into seven categories (Rockman et al., 51 2016; Fatorić and Seekamp, 2017). Financial constraints are the primary barriers that underpin the first four 52 adaptation options: no action at all, merely monitoring and/or documenting, or annual maintenance (Xiao et 53 al., 2019; Sesana et al., 2019; Fatoric and Seekamp, 2017; Fatorić and Seekamp, 2017; Fatorić and Seekamp, 54 2018). Core and shell preservation, the fifth and sixth categories, are cost effective when they improve the 55 condition of built cultural heritage (BCH) (Bertolin and Loli, 2018; Loli and Bertolin, 2018a; Loli and 56 Bertolin, 2018b), while elevation and/or relocation, the final adaptation options, are extremely costly and 57 might jeopardize the historic value (Xiao et al., 2019). To date, however, evidence indicates that adaptation ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 6 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 6-57 Total pages: 183 1 actions prioritize archaeological sites (Carmichael et al., 2017; Fatorić and Seekamp, 2018; Pollard et al., 2 2014; Dawson, 2013). The efficacy of adaptation of historic buildings can be increased through increased 3 and stable funding, incentives, stakeholder engagement, and legal and political frameworks (Dutra et al., 4 2017; Fatorić and Seekamp, 2018; Fatorić and Seekamp, 2017; Fatoric and Seekamp, 2017; Leijonhufvud, 5 2016; Phillips, 2015; Sesana et al., 2019; Sesana et al., 2018; Sitas, 2020). | 1167 - 116 | 'rot-Adapt-Mitig-Impa( | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 6 7 Other barriers to implementation include harnessing expert and local knowledge (of individuals and 8 organizations) to identify both quantitative and qualitative methods and indicators that connect cultural 9 significance and local values vis-à-vis climatic change over time and that move beyond the prevalent high 10 risk- or high vulnerability-centred approaches (Carmichael et al., 2017; Fatorić and Seekamp, 2018; Haugen 11 et al., 2018; Leijonhufvud, 2016; Pollard et al., 2014; Puente-Rodríguez et al., 2016; Richards et al., 2018; 12 Dawson, 2013; Filipe, Renedo and Marston, 2017; Kotova et al., 2019). This is particularly important given 13 that the significance of cultural heritage is often intangible, and its value cannot be determined solely 14 through quantitative indicators. Accessing local resources (craftsmanship and materials compatible with the 15 originals) can also improve built cultural heritage's adaptation capacity (Phillips, 2015). | 1168 - 116 | 'rot-Adapt-Mitig-Impa( | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 16 17 Effective decision making and practice for adapting built and intangible cultural heritage requires open 18 dialogue and exchange of cultural, historical and technical information between diverse stakeholders and 19 decision-makers (Fatorić and Seekamp, 2017; Benson, Lorenzoni and Cook, 2016). As noted in Section 20 6.2.6, human behaviour can be a driving force for adaptation impacts on built cultural heritage at risk. | 1168 - 116 | 'rot-Adapt-Mitig-Impa( | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | Effective decision making and practice for adapting built and intangible cultural heritage requires open 18 dialogue and exchange of cultural, historical and technical information between diverse stakeholders and 19 decision-makers (Fatorić and Seekamp, 2017; Benson, Lorenzoni and Cook, 2016). As noted in Section 20 6.2.6, human behaviour can be a driving force for adaptation impacts on built cultural heritage at risk. 21 Despite challenges associated with intangibility, socio-cultural heritage such as Indigenous knowledge (e.g. 22 food security and water management practices) presents important opportunities for climate adaptation and 23 resilience building. More research is needed across diverse contexts to understand feasible climate adaptation 24 measures and barriers and opportunities for building the resilience of both built and intangible cultural 25 heritage, as well as to increase awareness of cultural heritage benefits among climate change policymakers 26 (Fatorić and Egberts, 2020). | 1168 - 116 | 'rot-Adapt-Mitig-Impa( | INTANBILE | INDG |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 22 food security and water management practices) presents important opportunities for climate adaptation and 23 resilience building. More research is needed across diverse contexts to understand feasible climate adaptation 24 measures and barriers and opportunities for building the resilience of both built and intangible cultural 25 heritage, as well as to increase awareness of cultural heritage benefits among climate change policymakers 26 (Fatorić and Egberts, 2020). | 1168 - 116 | Prot-Adapt-Mitig- | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 26 Public actors can benefit from the private sector's innovation and implementation capacity, and businesses 27 can de-risk investments. Still, partnerships can also strengthen the ideologies of growth and managerialism 28 within the operations of the local government (Taylor et al., 2012). Reconciling divergent norms and routines 29 within public and private organizations remains one of the challenges to establishing successful public- 30 private partnerships for adaptation (Lund, 2018). Administrative and political culture influences the nature of 31 interactions between public and private sector actors in urban adaptation agendas (Bauer and Steurer, 2014) 32 with negative consequences such as the imposition of vertical chains of commands on horizontal 33 collaborations, and the need to formalize contractual relations (Klein and Juhola, 2018). | 1193 - 119 | 'rot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | 56 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 6 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 6-83 Total pages: 183 1 Unnikrishnan et al (2018) have documented how the colonial and postcolonial history of water management 2 in Bengaluru shapes the water infrastructure and provision systems today. Water access inequalities can be 3 traced to the patterns of spatial development developed by colonial policies. Records from the 6th century 4 onwards show how city rulers invested in an interconnected, community-managed network of tanks and 5 open wells, regularly recharged through harvested rainwater. The water system was changed at the end of the 6 18th century, as first the colonial state, then the post-independence government of Karnataka took 7 responsibility for water management. Ideas of modernist planning influenced the development of new water 8 infrastructure and piped networks, including the first piped infrastructure, bringing water from sources 30km 9 away, including the Hesaraghatta and then the TG Halli reservoirs. The old network of tanks gradually 10 deteriorated as tanks became disused, polluted, or built over. More prolonged and costly water transfers took 11 place in the post-colonial period, delivering water from the Cauvery river in a massive engineering project 12 with a high energetic cost and enmeshed in inter-state conflicts over water use (Castán Broto and Sudhira, 13 2019). Scarcity is still a problem in Bengaluru. The citizen response has been an activist movement to 14 reclaim the city's tanks, accompanied by a plea to reconsider current water uses within the city, including 15 actions to protect and rejuvenate water wells (Nagendra, 2016). Unnikrishnan et al (2018) document 16 different actions led by citizen-led collectives, including projects for lake rejuvenation, filtering technologies 17 to treat sewage, recovering the value of lakes through a share of photos and art projects, and involvement of 18 local knowledge in-tank restoration. Those efforts suggest an untapped potential to deliver adaptive green 19 spaces through the recovery of Bengaluru's tanks. | 1193 - 119 | Prot-Adapt-Mitig- | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 5 6 7 Table 6.7 Barriers to climate adaptation Examples of barriers to climate adaptation Institutional changes to overcome those barriers Examples Evidence Lack of financial resources Strategic combination of municipal, regional and national level funds Access to multiple financing mechanisms In European countries, large cities tend to fund their own adaptation, while smaller settlements depend on regional or national funding (Aguiar et al., 2018) (Moser et al., 2019) Lack of human resources and capacities Development of formal and informal partnerships, cooperative agreements and inter�agency arrangements International cooperation programmes for adaptation in urban areas in the Global South are most likely to succeed if they can align their objectives with local priorities and capacities (UN-Habitat, 2016b) Political commitment and willingness to act Use of policy windows and extreme events to generate interest and create lasting responses In Germany, responses to flooding were strongly shaped by public perceptions of safety during the electoral cycle, leading to inadequate responses (Gawel et al., 2018; Di Giulio et al., 2018) Uncertainty about future impacts and dynamic interactions Develop institutional arrangements that acknowledge and reduce uncertainty Facilitate the development of bottom�up initiatives that relate directly to the context of action Power plant operators and the federal state of Baden-Württemberg negotiated the minimum power plant concept ("Mindestkraftwerkskonzept", MPP), a contract to establish more predictable and workable procedures for curtailment in the event of severe heat waves (Eisenack, 2016) (Thaler et al., 2019) Institutional fragmentation and unclear responsibilities Evaluation of existing institutions to diagnose miscoordination Creation of policy networks that address emerging interdependences In settlements in Languedoc, France, decentralisation adds complexity to the ongoing challenges of population growth and climate change (Therville et al., 2019) Legal issues and regulations Address the legal hurdles to create frameworks that allow for experimental action Policy makers in the San Francisco Bay Area, US reported that minor changes could have a definitive influence in delivering regulatory changes to support adaptation action In The Netherlands, a lack of climate change adaptation policy for cultural heritage hamper adaptation of cultural heritage to current and projected climate risks (Ekstrom and Moser, 2014) (Fatorić and Biesbroek, 2020) Competition of adaptation with other policy agendas and polarisation Prioritization and development of synergies across sectors Mainstreaming adaptation into other sectors In European cities, for example, urban planning is strongly correlated with water management strategies (Aguiar et al., 2018) (Sieber, Biesbroek and de Block, 2018) Lack of data, knowledge generation capacity, and knowledge exchange Mobilise multiple strategies for the use of climate information in local decision-making In Scotland, Hungary and Portugal local decision makers use HECC scenarios, but most often as background data (Lourenço et al., 2019) (Herrmann and Guenther, 2017) ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 6 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 6-85 Total pages: 183 Involve a wide range of stakeholders- with different values and knowledge- in decision making Sharing knowledge alongside the supply chain favours adaptation for both multinationals and SMEs (Gotgelf, Roggero and Eisenack, 2020) (Wamsler, 2017) 1 2 3 Institutional change, is needed to open new options for inclusive and sustainable adaptation and to integrate 4 adaptation and mitigation (robust evidence, high agreement) (see also Section | 1195 - 119 | Prot-Adapt-Mitig-Impact | | |
| IPCC_AR6_WGII_Full_Report | 31 Municipalities in Sweden have been called 'pre-reactive' because adequate strategic guidelines are in place 32 to frame the accessibility, aesthetics, and adaptability of waterfront developments (Storbjörk and Uggla, 33 2015). Some Asian cities also report high output effectiveness, where they are more likely to indicate senior 34 local government officials' performance management contracts, the budgeting procedures of local 35 government agencies, and the procedures that local government agencies use for budgeting infrastructure 36 spending (Aylett, 2015). Despite this evidence, there is a gap in understanding the general trends of planning 37 and institutional change in Africa, Asia, East Europe and the Middle East. | 1197 - 119 | Prot-Adapt-Mitig-Impac | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 41 42 43 [START BOX 6.7 HERE] 44 45 Box 6.7: The Role of Urban Design in Local Adaptation 46 47 Since AR5 there has been a growing literature about the role of urban design, creating new opportunities for 48 both incremental and transformative adaptive responses to climate change (medium evidence, high 49 agreement). For example some of these creative design approaches compliment and extend regulatory and 50 land use planning approaches such as form-based codes and established certifications like LEED-ND 51 (Leadership in Energy and Environmental Design – Neighbourhood Design) (Garde, 2018; Garde and Hoff, 52 2017) and the USA's Sustainable Sites Initiative (SITES) (Valente, 2014). Emphasis on sufficiency has also 53 influenced urban design, for example, with the mobilization of 'doughnut' economics that emphasize both a 54 social foundation and an environmental ceiling, for example Amsterdam (Raworth, 2017). However, such 55 cases are rare, substantial public investment is often required (high confidence, high agreement) (see also 56 section 6.4.7 on finance and insurance). Other approaches underscore innovation and creativity, at the 57 essence of which are context-specific interventions that draw on a compendium of urban design principles ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 6 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 6-94 Total pages: 183 1 such as: indeterminacy (to accommodate climate uncertainty), polyvalency and diversity, and harmony with 2 nature (Dhar and Khirfan, 2017a). Creative interventions include the daylighting of buried streams to create 3 climate adaptive public realms (Khirfan et al., 2020; Khirfan, Mohtat and Peck, 2020). For example, the 4 demolition of a major expressway and the restoration of the Cheonggyecheon stream reorganised downtown 5 Seoul, South Korea and significantly contributed to climate change adaptation through stormwater 6 management and reducing the urban heat island effect (Kim and Jung, 2019). Biomimicry and ecological 7 infrastructure are design features that governance bodies can use to reshape space and contribute to place 8 making (Santos Nouri and Costa, 2017; Prior et al., 2018). For example, urban metabolism and local 9 ecological knowledge has constituted the essence of urban design interventions in the Island of Tobago in 10 ways that capitalize on the contiguous relationship between ecosystems (e.g., the mangrove forest) and 11 human actions (rainwater harvesting and grey water management) (Khirfan and Zhang, 2016). While lack of 12 funding, or design capacity, restrictive planning regulations, inequality and competing urban agendas can 13 create barriers for the implementation of creative design solutions, transition architecture movements are also 14 driving local urban adaptation experiments and exploring ways local learning can be scaled up (Tubridy, 15 2020; Irwin, 2019). | 1204 - 12C | ʼrot-Adapt-Mitig-Impa | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 39 Paradigm changes, such as new engagements with nature and green infrastructure, will improve adaptation 40 outcomes (Roberts et al., 2012). Changes of paradigms, however, are not inherently positive and may clash 41 with existing interests or involve trade-offs with other priorities. When care is taken to ensure greater 42 inclusion in urban decision making, disadvantaged, vulnerable communities are less likely to be 43 disadvantaged. For example, indigenous traditions of nature management provide entry points for the 44 sustainable management of resources, such as seed banks, urban agriculture, and the local management of 45 watersheds and floods, may be at odds with conventional structures of expert knowledge (Cid-Aguayo, 2016; 46 Chandra and Gaganis, 2016). These traditions are vital both because of the solution space that they open in 47 the local context and how they serve to create resilience through collective and intergenerational learning 48 (Chandra and Gaganis, 2016). | 1214 - 121 | Prot-Adapt-Mitig- | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 54 55 The City of Semarang first engaged with climate change in 2009, when the Rockefeller Foundation launched 56 the Asian Cities Climate Change Resilience Network (ACCCRN), an initiative to develop resilience capacity 57 across secondary and rapidly growing cities in South and Southeast Asia (Reed et al., 2015). Semarang was a ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 6 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 6-107 Total pages: 183 1 pilot city for ACCCRN from 2009 to 2016, when it introduced a participatory approach to planning and 2 decision-making that challenged the government-dominated tradition in the city, and in turn played a key 3 role in Semarang's climate adaptation and resilience planning process (Orleans Reed et al., 2013; Moench, 4 2014; Kernaghan and Da Silva, 2014). A City Team was formed in 2010 consisting of City Environmental 5 Agency (BLH – Badan Lingkungan Hidup), Regional Disaster Management Agency (BPBD - Badan 6 Penanggulangan Bencana Daerah), Water Resources Management Office (PSDA - Kantor Dinas 7 Pengelolaan Sumber Daya Air), Regional Planning and Development Agency (BAPPEDA - Badan 8 Perencanaan Pembangunan Daerah), local universities, and NGOs such as the Bintari Foundation, with 9 technical support from Mercy Corps Indonesia (Nugraha and Lassa, 2018). | 1217 - 121 | Prot-Adapt-Mitig- | INTANBILE | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 29 30 Xi'xian aims to build a 'modern garden city' when it was selected as national demonstration sites for Sponge 31 City (SC) during 2015-2018 and Climate Resilient City (CRC) during 2017-2020. Under the changing 32 climate, the old cities of Xi'xian suffers urban heat island, drying and water scarcity, heavy rains and 33 waterlogging, thunderstorm and so on, which bring adverse effects to transportation, construction, cultural 34 relics tourism resources, and other industries (Ma, Yan and Zeyu, 2021). Sponge City status requires 35 innovation to reduce flood risk through design to absorb, store, and purify rainfall and storm water in an 36 ecologically friendly way that reduces dangerous and polluted runoff. When required, the stored water is 37 released and added to the urban water supply (MoHURD, 2014). As Climate Resilient City the aim is to 38 adapt to climate risk and environmental change, by integrating climate resilience into urban renewal and 39 revitalization. | 1219 - 121 | 'rot-Adapt-Mitig-Impact | | |
| IPCC_AR6_WGII_Full_Report | 33 34 Efforts to adapt to climate change can be incremental, reformist, or transformational, depending on the scale 35 of the change required. Incremental action may address specific climate impacts in a given place, but do not 36 challenge the social and political institutions that prevent people from bouncing back better. Reformist action 37 may address some of the social and institutional drivers of exposure and vulnerability, but without 38 addressing the underlying socio-economic structures that drive differential forms of exposure. For example, 39 social protection measures may improve people's capacity to cope with climate impacts, but that improved 40 capacity will depend on maintaining such protection measures. Transformative action involves fundamental 41 changes in political and socio-economic systems, oriented towards addressing vulnerability drivers (e.g., 42 socio-economic inequalities, consumption cultures). All forms of adaptation are relevant to deliver resilient 43 futures because of the variability of conditions in which adaptation action is needed. | 1231 - 123 | 'rot-Adapt-Mitig-Impa | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 21 22 7.1.3.2 IPCC Special Reports 23 24 All three post-AR5 IPCC Special Reports considered some of the research that is assessed here in greater 25 detail. The 2018 report on 1.5° C (SR1.5) included a review of climate change and health literature published 26 since AR5 and called for further efforts for protecting health and wellbeing of vulnerable people and regions 27 (Ebi et al., 2018b), and highlighted links between climate change hazards, poverty, food security, migration, 28 and conflict. The 2019 Special Report on Climate Change and Land (SRCCL) (SRCCL, 2019) emphasized 29 the impacts of climate change on food security; highlighted links between reduced resilience of dryland 30 populations, land degradation migration, and conflict; and raised concerns about the impacts of climate 31 extremes. The 2019 Special Report on the Ocean and Cryosphere in a Changing Climate (Pörtner et al., 32 2019) detailed how changes in the cryosphere and ocean systems have impacted people and ecosystem 33 services, particularly food security, water resources, water quality, livelihoods, health and wellbeing, 34 infrastructure, transportation, tourism, and recreation, as well as the culture of human societies, particularly 35 for Indigenous peoples. It also noted the risks of future displacements due to rising sea levels and associated 36 coastal hazards. | 1304 - 130 | 'rot-Adapt-Mitig-Impa | | INDG |
| IPCC_AR6_WGII_Full_Report | 48 49 There is no consensus definition of wellbeing, but it is generally agreed that it includes a predominance of 50 positive emotions and moods (e.g. happiness) compared with extreme negative emotions (e.g. anxiety), 51 satisfaction with life, a sense of meaning, and positive functioning, including the capacity for unimpaired 52 cognitive functioning and economic productivity (Diener and Tay, 2015) (Piekałkiewicz, 2017). A 53 capabilities approach (Sen, 2001) focuses on the opportunity for people to achieve their goals in life (Vik 54 and Carlquist, 2018) or the ability to take part in society in a meaningful way: the result of personal 55 freedoms, human agency, self-efficacy, an ability to self-actualize, dignity and relatedness to others 56 (Markussen et al., 2018). An Indigenous perspective on wellbeing is broad and typically incorporates a 57 healthy relationship with the natural world (Sangha et al., 2018); emotional and mental health have also been ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 7 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 7-11 Total pages: 181 1 linked to a strong cultural identity (Butler et al., 2019);(Dockery, 2020). "Health" itself is sometimes 2 described as including relationships between humans and nature as well as links to community and culture 3 (Donatuto et al., 2020);(Dudgeon et al., 2017) 4 5 Subjective wellbeing is consistently associated with personal indicators such as higher income, greater 6 economic productivity, better physical health (Diener and Tay, 2015);(Delhey and Dragolov, 2016);(De 7 Neve et al., 2013), and environmental health; and associated with societal indicators such as social cohesion 8 and equality (Delhey and Dragolov, 2016). In a global sample of over 1 million people obtained between 9 2004-2008 via the Gallup World Poll, annual income and access to food were strong predictors of subjective 10 wellbeing, and a healthy environment, particularly access to clean water, was also associated even when 11 household income was controlled (Diener and Tay, 2015). Access to green spaces is also associated with 12 wellbeing (high confidence) (Lovell et al., 2018);(Yuan et al., 2018). | 1304 - 1305 | | INTANBILE | INDG |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 7 8 7.1.7.3.6 Indigenous People 9 Indigenous Peoples, especially those that live in geographically isolated, resource-dependent, and/or 10 impoverished communities, are often at greater risk of health impacts of climate change (Ford et al., 2020) 11 (USGCRP, 2016). The close interconnection of land-based livelihoods and cultural identity of many 12 Indigenous groups exposes them to multiple health- and nutrition related hazards (Durkalec et al., 13 2015);(Sioui, 2019), with potential implications for community social relations and for individuals' mental 14 health (Cunsolo Willox et al., 2013);(Cunsolo Willox et al., 2015). Climate change risk exposures may be 15 complicated by changes in lifestyle, diet, and morbidity driven by socio-economic processes, further 16 increasing health risks for Indigenous peoples (Jaakkola et al., 2018). Environmental consequences of 17 climate change can also affect social ties and spiritual wellbeing, in part because land is often an integral part 18 of their culture and spiritual identity. | 1310 - 131 | Impact | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 45 46 Tertiary effects relate to culture-wide changes; for example, all forms of malnutrition due to climate-driven 47 changes in food systems; and anxiety, mental illness, and suicidal thoughts related to cultural and spiritual 48 losses. A wide range of tertiary, culture-related effects of climate change have been documented for 49 Indigenous Peoples. These include anxiety, distress and other mental health impacts due to direct and 50 indirect processes of dispossession of land and culture related to the combination of climate change in and 51 other factors (Richmond and Ross, 2009);(Bowles, 2015);(Norton-Smith et al., 2016);(Jaakkola et al., 52 2018);(Fuentes et al., 2020);(Mamo, 2020);(Middleton et al., 2020b);(Middleton et al., 2020a);(Olson and 53 Metz, 2020);(Timlin et al., 2021). Increased risks of conflict and abuse, including violence and homicide 54 against females, and/or resulting from environment activism, are other tertiary health threats for Indigenous 55 Peoples (Mamo, 2020). Between 2017 and 2019, close to 500 Indigenous people were killed for activism in 56 19 different countries (Mamo, 2020). In Uganda, climate change drives Indigenous men to increase their ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 7 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 7-18 Total pages: 181 1 distance and time from home and their families in search of water, food, and water, leading to an increase in 2 sexual violence against Indigenous women and girls in their communities (Mamo, 2020). | 1311 - 131 | Impact | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 54 55 In a pilot project for climate adaptation of reindeer herding run by the Swedish Sami Parliament, reindeer 56 herding management plans (in Swedish, renbruksplaner) were used as a tool to develop strategies for climate 57 adaptation (Walkepää, 2019). Four Sami reindeer herding cooperatives participated in the pilot study. They ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 7 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 7-21 Total pages: 181 1 all agreed that climate change means that grazing patterns need to change. Traditionally, mountain reindeer 2 graze in the Scandinavian mountains close to Norway in summertime, and in the coastal areas close to the 3 Gulf of Bothnia in wintertime, representing a total migration route of up to 400 kilometres one-way. Rising 4 temperatures are causing spring to occur earlier in the coastal winter grazing land, before the calving areas in 5 the summer land are suitable for grazing and free from snow. When the snow cover disappears, the herds are 6 dispersed, so it is important to migrate while snow is still present (Walkepää, 2019). Migration routes are 7 being destabilized by weaker ice cover on water and by hazardous weather events. Competing land use due 8 to infrastructure, extractive industries, tourism, and energy production makes it difficult to find alternative 9 grazing land. Supplementary feeding and increased use of trucks to transport reindeer is one result. Herds 10 that are dispersed due to bad snow conditions have an increased exposure to predators (Walkepää, 2019 11 (Walkepää, 2019);(Uboni et al., 2020). By working strategically to secure adequate winter grazing and 12 reduce fragmentation of grazing areas more generally represents win-win strategies for achieving decreased 13 mental stress levels while reducing herders' consumption of fossil fuels (Walkepää, 2019). | 1314 - 131 | Prot-Adapt-Mitig-Impac | INTANBILE | |

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| IPCC_AR6_WGII_Full_Report | 40 sample, perceived ecological stress, defined as personal stress associated with environmental problems, 41 predicted depressive symptoms (Helm et al., 2018);in a sample of Filipinos, climate anxiety was correlated 42 with lower mental health (Reyes et al., 2021), and a non-random study in 25 countries showed positive 43 correlations between negative emotions about climate change and self-rated mental health (Ogunbode et al., 44 2021). However, an earlier study found no correlation between climate change worry and mental health 45 issues (Berry and Peel, 2015). Because the perceived threat of climate change is based on subjective 46 perceptions of risk and coping ability as well as on experiences and knowledge (Bradley et al., 2014), even 47 people who have not been directly affected may be stressed by a perception of looming danger (Clayton and 48 Karazsia, 2020). Not surprisingly, those who have directly experienced some of the effects of climate change 49 may be more likely to show such responses. Indigenous Peoples, whose culture and wellbeing tend to be 50 strongly linked to local environments, may be particularly likely to experience mental health effects 51 associated with changes in environmental risks; studies suggest connections to an increase in depression, 52 substance abuse, or suicide in some Indigenous Peoples (Canu et al., 2017);(Cunsolo Willox et al., 53 2013);(Middleton et al., 2020b);(Jaakkola et al., 2018). | 1340 - 134 | Impact | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 54 55 7.2.5.2 Observed Impacts on Wellbeing 56 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 7 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 7-47 Total pages: 181 1 Overall, research suggests that climate change has already had negative effects on subjective wellbeing 2 (medium confidence). Climate change can affect wellbeing through a number of pathways, including loss of 3 access to green and blue spaces due to damage from storms, coastal erosion, drought, or wildfires; heat; 4 decreased air quality; and disruptions to one's normal pattern of behaviour, residence, occupation, or social 5 interactions (Hayward and Ayeb-Karlsson, 2021). For example, substantial evidence shows a negative 6 correlation between air pollution and subjective wellbeing or happiness (Apergis, 2018);(Cunado and de 7 Gracia, 2013);(Lu, 2020);(Luechinger, 2010);(Menz and Welsch, 2010);(Orru et al., 2016);(Yuan et al., 8 2018);(Zhang et al., 2017a); in the reverse direction, there is evidence not only that time in nature but more 9 specifically a feeling of connectedness to nature are both associated with wellbeing (Martin et al., 2020) and 10 healthy ecosystems offer opportunities for health improvements (Pretty and Barton, 2020). Negative 11 emotions such as grief - often termed 'solastalgia'(Albrecht et al., 2007) -- are associated with the 12 degradation of local or valued landscapes (Eisenman et al., 2015);(Ellis and Albrecht, 2017);(Polain et al., 13 2011);(Tschakert et al., 2017);(Tschakert et al., 2019), which may threaten cultural rituals, especially among 14 Indigenous Peoples (Cunsolo and Ellis, 2018);(Cunsolo et al., 2020). Studies conducted in the Solomon 15 Islands and in Tuvalu found qualitative and quantitative evidence of experiences of climate change and 16 worry about the future, with negative impacts on respondents' wellbeing (Asugeni et al., 2015);(Gibson et 17 al., 2020). | 1340 - 134 | Impact | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 55 56 7.2.6 Observed Impacts on Migration 57 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 7 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 7-48 Total pages: 181 1 Consistent with peer-reviewed scholarship and with the UNFCCC Cancun Adaptation Framework section 2 14(f) and the Paris Agreement, this Chapter assesses the impacts of climate change on four types of 3 migration: 1) adaptive migration (i.e where migration is an outcome of individual or household choice ); (2) 4 involuntary displacement (i.e. where people have few or no options except to move); (3) organized 5 relocation of populations from sites highly exposed to climatic hazards; and (4) immobility (i.e. an inability 6 or unwillingness to move from areas of high exposure for cultural, economic or social reasons) (see Cross- 7 Chapter Box MIGRATE). | 1341 - 134 | 'rot-Adapt-Mitig-Impa( | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 39 40 7.2.6.2 Immobility and Resettlement in the Context of Climatic Risks 41 42 Immobility in the context of climatic risks can reflect vulnerability and lack of agency (i.e., inability to 43 migrate), but can also be a deliberate choice (high confidence). Research since AR5 shows that immobility 44 is best described as a continuum, from people who are financially or physically unable to move away from 45 hazards (i.e. involuntary immobility) to people who choose not to move (i.e. voluntary immobility) because 46 of strong attachments to place, culture, and people (Nawrotzki and DeWaard, 2018); (Adams, 47 2016);(Farbotko and McMichael, 2019);(Zickgraf, 2019);(Neef et al., 2018);(Suckall et al., 2017);(Ayeb- 48 Karlsson et al., 2018);(Zickgraf, 2018);(Mallick and Schanze, 2020). Involuntary immobility is associated 49 with individuals and households with low adaptive capacity and high exposure to hazard and can exacerbate 50 inequality and future vulnerability to climate change (Sheller, 2018), including through impacts on health 51 (Schwerdtle et al., 2018). Voluntary immobility represents an assertion of the importance of culture, 52 livelihood and people to wellbeing, and is of particular relevance for Indigenous Peoples (Suliman et al., 53 2019). | 1352 - 135 | 'rot-Adapt-Mitig-Impa( | | INDG |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 5 6 Examples of relocations of small Indigenous communities in coastal Alaska and villages in the Solomon 7 Islands and Fiji suggest that relocated people can experience significant financial and emotional distress as 8 cultural and spiritual bonds to place and livelihoods are disrupted (Albert et al., 2018);(Neef et al., 9 2018);(McMichael and Katonivualiku, 2020);(McMichael and Katonivualiku, 2020);(McMichael et al., 10 2021);(Piggott-McKellar et al., 2019);(Bertana, 2020). Voluntary relocation programs offered by US state 11 governments in communities damaged by 2012's Hurricane Sandy have been subject to multiple studies, and 12 these show participants' longer term economic outcomes, social connections and mental wellbeing can 13 compare either favourably or unfavourably with non-participants for a range of reasons unrelated to the 14 impacts of the hazard event itself (Bukvic and Owen, 2017);(Binder et al., 2019);(Koslov and Merdjanoff, 15 2021), 16 17 18 [START BOX 7.4 HERE] 19 20 Box 7.4: Gender Dimensions of Climate-related Migration 21 22 Migration decision-making and outcomes – in both general terms and in response to climatic risks – are 23 strongly mediated by gender, social context, power dynamics, and human capital (Bhagat, 2017);(Singh and 24 Basu, 2020);(Rao et al., 2019a);(Ravera et al., 2016). Women tend to suffer disproportionately from the 25 negative impacts of extreme climate events for reasons ranging from caregiving responsibilities to lack of 26 control over household resources to cultural norms for attire (i.e. saris in South Asia) (Belay et al., 27 2017);(Jost et al., 2016). In many cultures, migrants are most often able-bodied, young men (Call et al., 28 2017);(Heaney and Winter, 2016). Women wait longer to migrate because of higher social costs and risks 29 (Evertsen and Van Der Geest, 2019) and barriers such as social structures, cultural practices, lack of 30 education, and reproductive roles (Belay et al., 2017);(Afriyie et al., 2018);(Evertsen and Van Der Geest, 31 2019)). | 1353 - 135 | Impact | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 38 Nature-based solutions (NbS) to reduce heat that offer co-benefits for ecological systems include green and 39 blue infrastructure (e.g., urban greening/forestry and the creation of water bodies) (Koc et al., 2018);(Lai et 40 al., 2019);(Shooshtarian et al., 2018);(Ulpiani, 2019);(Zuvela-Aloise et al., 2016), (Hobbie and Grimm, 41 2020). The implementation of climate-sensitive design and planning can be constrained by governance 42 issues;(Jim et al., 2018) and the benefits are not always evenly distributed among residents. Implementation 43 of climate-sensitive design and NbS does, however, need to be carried out within the context of wider public 44 health planning because water bodies and moist vegetated surfaces provide suitable habitats for a range of 45 disease vectors;(Nasir et al., 2017);(Tian et al., 2016);(Trewin et al., 2020). Solutions recommended for 46 managing exposure to heat in outdoor workers include improved basic protection (including shade, planned 47 rest breaks), heat-appropriate personal protective equipment, work scheduling for cooler times of the day, 48 heat acclimation, improved aerobic fitness, access to sufficient cold drinking water, and on-site cooling 49 facilities and mechanisation of work (Morabito et al., 2021);(Morris et al., 2020);(Varghese et al., 50 2020);(Williams et al., 2020). | 1385 - 138 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | 20 21 Because mental health is fundamentally intertwined with social and economic wellbeing, adaptation for 22 climate-related mental health risks benefits from wider multi-sectoral initiatives to enhance wellbeing, with 23 the potential for co-benefits to emerge (high confidence). Improvements in education, quality of housing, 24 safety, and social protection support enhance general wellbeing and make individuals more resilient to 25 climate risks (Lund et al., 2018);(Hayes et al., 2019). Among Indigenous Peoples, connections to traditional 26 culture and to place are associated with health and wellbeing (Bourke et al., 2018) as well as with resilience 27 to environmental change (Ford et al., 2020). As an example of the connection between infrastructure 28 improvements and mental health, a study of domestic rainwater harvesting initiatives to promote household 29 water security also improved mental health in participating households (Mercer and Hanrahan, 2017). | 1392 - 139 | 'rot-Adapt-Mitig-Impa( | INTANBILE | INDG |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 11 12 13 Table 7.9: Characteristics of health systems under SSPs 1, 2, and 3. Modified from Sellers and Ebi (2017) (Sellers and 14 Ebi, 2017) SSP3 SSP2 SSP1 Basic characteristics Reactive; failure to adapt; siloed information channels and national governance; limited partnerships Incomplete planning; new information incorporated as convenient; occasional partnerships Proactive; adaptively managed; frequent partnerships; interdisciplinary Leadership and governance Little focus at national and international levels on climate change and health; minimal planning conducted Planning on climate change and health, but not comprehensive and often side�tracked on other issues Strong climate change and health planning apparatus, including health components of national adaptation plans; regional / international partnerships Health workforce Climate change and health not rarely incorporated into training; few provisions for new training programs or funding for increase health worker positions in climate change-relevant specialties; health disparities not addressed Climate change and health not systematically incorporated into training; new training programs insufficient to fill gaps in demand; limited attention to addressing health disparities Systematic inclusion of climate change and health in worker training; expansion of funding and training; financing and incentive mechanisms to address health disparities ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 7 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 7-111 Total pages: 181 Health information systems Assessments of vulnerability and adaptation rarely, if ever conducted; information not useful for planning; minimal risk monitoring or research Vulnerability and adaptation assessments occasionally conducted, but generally of poor quality; early warnings incomplete; fiscal and political constraints on research Vulnerability and adaptation assessments regularly conducted and used in planning; robust early warning networks; research agenda focused on vulnerable communities Climate resilient and sustainable technologies and infrastructure Facilities sited and constructed without climate consideration incorporated; medical supply chains no modified Capital cost serves as key factor in siting and construction; increasing vulnerability of facilities to shocks Health infrastructure designed to be robust to storms/floods, with redundant systems added to ensure continuity of care Service delivery Policies to manage environmental health hazards generally not followed; care practices not modified to accommodate climate information; few changes to emergency management procedures; health inequities worsen Environmental health policies are not robust; marginal improvements in care practices; risk assessments and communication inadequate; no shift in health inequities Policies to manage environmental health hazards regularly reviewed; practitioners review care practices and adjust as appropriate based on local climate and health conditions; robust communication tools developed; health service improvements reduce health inequities Climate and health financing Few funds devoted to climate change and health activities, particularly in low- and middle-income countries; few if any financing partnerships between high- and low- and middle-income countries; very weak regional and international coordinating bodies due to funding constraints High-income countries generally form robust financing mechanisms; fiscal pressures in low- and middle-income countries constrain their financing abilities; financial partnerships formed across countries, but financing often not robust; regional and international coordinating bodies receive inadequate funds Robust funding streams for | 1404 - 140 | Prot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGII_Full_Report | 7 8 Shifting to sustainable food systems that provide affordable diverse plant-rich diets with moderate quantities 9 of GHG-intensive animal protein can bring health co-benefits and substantially reduce GHG emissions, 10 especially in high income countries and where ill health related to overconsumption of animal-based 11 products is prevalent (very high confidence). {5.12.6, WGII} {7.4, 13.5, WGII} {5.WGIII} (7.4 WGIII) 12 (Springmann et al., 2018c);(SRCCL, 2019); (Clark and Tilman, 2017); (Poore and Nemecek, 2018); (Hayek 13 et al., 2021). Transforming the food system by limiting the demand for GHG-intensive animal foods, 14 reducing food over-consumption and transitioning to nutritious, plant-rich diets, can have significant co- 15 benefits to health (high confidence) (Hedenus et al., 2014); (Ripple et al., 2014);(Tirado, 2017); (Springmann 16 et al., 2018c); IPCC SR1.5, 2018). (SROC 2019).(SRCCL, 2019); (Nelson et al., 2016); (Willett et al., 17 2019);(Tilman and Clark, 2014);(Green et al., 2015);(Springmann et al., 2016b);(Springmann et al., 18 2018b);(Springmann et al., 2018a);(Springmann et al., 2018c); (Milner et al., 2015);(Milner et al., 19 2017);(Farchi et al., 2017);(Song et al., 2017); (Willett et al., 2019). Reduction of red meat consumption 20 reduces the risk of cardiovascular disease and colorectal cancer; and the consumption of more fruits and 21 vegetables can reduce the risk of cardiovascular disease, type II diabetes, cancer, and all causes of mortality 22 (WHO, 2015c);(Tilman and Clark, 2014);(Sabate and Soret, 2014); (Willett et al., 2019). {7.4 WGIII} 23 {5.12.5 WGII} {6.3 WGIII}. Globally, it is estimated that transitioning to more plant-based diets - in line 24 with WHO recommendations on healthy eating - could reduce global mortality by 6–10% and food-related 25 greenhouse gas emissions by 29–70% by 2050 (Springmann et al., 2016b). There are limitations in 26 accessibility of affordable of healthy and diverse diets for all (Springmann et al., 2020) and trade-offs such 27 as the potential increase of GHG emissions from producing healthy and diverse diets in low- and medium- 28 income countries (Semba et al. 2020). Agroecological approaches have mitigation and adaptation potential, 29 deliver ecosystem services, biodiversity, livelihoods and benefits to nutrition, health, and equity (Rosenstock 30 et al., 2019);(Bezner Kerr et al., 2021);{5.4.4; 5.14.1 WGII} {13.5, 14.4.4 WGII}. | 1409 - 140 | Prot-Adapt-Mitig-Impac | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 24 25 [END BOX 8.1 HERE] 26 27 28 8.2.1.6 Interactions between climate hazards and social-ecological thresholds 29 30 Climate change threatens to rapidly transform unique and threatened ecosystems (RFC1), such as tropical 31 rain forests, coral reefs, arctic and high-mountain ecosystems, as well as the Indigenous and forest-dwelling 32 people whose livelihoods, cultures and identities are dependent on these ecosystems. In recent years, the case 33 of Amazonia illustrates how such systems are transforming, with detrimental consequences for Indigenous 34 Peoples, and the vital role that Indigenous Peoples serve in protecting vulnerable ecosystems (Ricketts et al., 35 2010; Box 8.6). Globally, Indigenous territories cover the greatest area of remaining tropical forest in 36 comparison to other protected areas, and encompass the bulk of Earth's biodiversity, and are the locus for a 37 number of key ecosystem services across spatial and temporal scales(Walker et al., 2020). Specifically, in 38 2014 Indigenous territories and other protected areas represented the equivalent of 58.5% of all the carbon 39 stored in the Brazilian Amazon biome and had the lowest deforestation rate (2.1%) and fire incidences, 40 evidencing the effectiveness in safeguarding important ecosystems services and wellbeing (Nogueira et al., 41 2018). It is estimated that Indigenous territories in the Brazilian Amazon contribute at least US$5 billion 42 each year to the global economy through food and energy production, greenhouse emissions offsets, and 43 climate regulation and stability (Siqueira-Gay et al., 2020). Given the high incidence of poverty of the 44 Amazonian countries and high proportion of traditional and Indigenous Peoples, remoteness and neglected 45 governance place these unique ecosystems and Indigenous populations as highly vulnerable to climate 46 change impacts (Pinho et al., 2014; Brondízio et al., 2016; Mansur et al., 2016; Kasecker et al., 2018). | 1492 - 149 | Prot-Adapt-Mitig-Impa | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 55 56 Overall, this case study illustrates the benefits of promoting resilient crop production in Gargey Village, as 57 an example of displaced atoll communities. Innovative and sustainable CSA strategies offered broader ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 8 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 8-20 Total pages: 155 1 insights and lessons for enhancing adaptive capacity and resilience, on a degraded landscape. The coherent 2 strategies and methods employed strengthened livelihood opportunities by improving access to services, 3 knowledge, and resources. By its concurrent focus on enhancing food security through traditional crops, 4 coupled with nutrient-rich vegetables, promoting rainwater-harvesting systems and water conservation, and 5 promoting resilient household livelihood opportunities, atoll communities brought together crucial elements 6 needed to reduce vulnerabilities, and to better cope with disasters and climate extremes while embracing the 7 traditional culture. The location-specific yet knowledge-intensive CSA methods deployed, offered 8 opportunities for atoll communities to revitalize themselves, overcoming barriers while adjusting to new 9 landscapes. | 1494 - 149 | Prot-Adapt-Mitig- | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 29 Climate change impacts can also heighten existing gender inequalities (Jost et al., 2016; Glazebrook et al., 30 2020). On the one hand, climate change impacts can be gendered as a result of customary roles in society, 31 such as triple workloads for women (i.e., economic labour, household and family labour as well as duties of 32 community participation), and occupational hazards from gendered work indoors and outdoors (Murray et 33 al., 2016). On the other, climate change hazards interact with changing gender roles in society, such as urban 34 migration of both men and women in ways that break with tradition (Bhatta et al., 2016). | 1502 - 150 | Impact | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 23 24 Impacts of climate change are affecting the economic and non-economic dimensions of people's lives, 25 including subsistence practices of communities that are experiencing decreases in agriculture productivity 26 and quality, water stress, increases in pests and diseases, disruption to culture, and emotional and 27 psychological distress, just to cite a few (Savo et al., 2016). For example, the cumulative effects of slow- 28 onset events threaten food security especially among the poor in Latin America and the Caribbean—regions 29 which face the largest gender gap in terms of food security globally (Zuñiga et al., 2021). In general for 30 Global South countries, the global average temperature warming (including the Paris target of 1.5°C) means 31 substantially higher warming and including higher frequency and magnitude of extreme events, that will 32 result in significant impacts on societal vulnerability (Aitsi-Selmi and Murray, 2016; Djalante, 2019). | 1519 - 151 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 5 6 A pertinent example of economic losses is the example of the Torres Strait in Australia. This example shows 7 evidence of communities living on remote islands Boigu, a low-lying mud island inundated by the sea during 8 high tides and storm surges, and those most exposed and vulnerable to climate change have limited 9 livelihood assets and face challenges to secure external support with government and others. Place-based 10 values evoke a reluctance to relocate or retreat with economic losses such as community infrastructure, 11 housing, and cultural sites (McNamara et al., 2017). In the Great Barrier Reef, Australia sea level rise and 12 sea level global temperature warming affects fisheries productivity and tourism (Evans et al., 2016). | 1521 - 1521 | | INTANBILE | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 26 27 Extreme climate events are disproportionately impacting economies of the most vulnerable everywhere 28 (medium evidence, high agreement). In the United States, Central America and Caribbean, Hurricanes 29 Katrina, Harvey, Irma, Maria and Michael are examples of extreme climate events that have displaced 30 households, destroyed homes, and led to loss of income among the poor and marginalized (Klinenberg et al., 31 2020). Puerto Rico was devastated by Maria but received less support from the Federal Emergency 32 Management Agency (FEMA) (García, 2021). Evidence is emerging on unequal governance response in the 33 US versus Puerto Rico (Joseph et al., 2020). Floods, storms and heatwaves have impacted the poorer 34 communities, and even wildfires in California, impact many wealthy groups, also impacted infrastructure 35 used by all, for example, with lengthy electrical power blackouts, but particularly impacted vulnerable to 36 disasters such as undocumented Latino/a and Indigenous immigrants in the case of the Thomas Fire in 37 California's Ventura and Santa Barbara counties(Méndez et al., 2020) Hurricane Irma in 2017 hit Ragged 38 Island in the Bahamas as a category 5 storm leaving the island in ruins and deemed 'unlivable' by its 39 authorities, with most infrastructure left as rubble, no essential utilities remained, schools and health clinics 40 were in ruins and the stench of dead animals was overwhelming. This storm resulted in signiffcant economic 41 loss and damage by the community through loss of their homes, churches, schools, agricultural land, and 42 infrastructure (Thomas and Benjamin, 2020). | 1521 - 152 | Impact | | INDG |
| IPCC_AR6_WGII_Full_Report | 20 21 Non-economic loss and damage (NELD) is values based (subjective and intangible) and relates to norms, 22 social values and highlights intersectional experiences and perspectives on climate risk. The discourse on 23 loss and damage includes a framing of NELD as loss of human and non-human life and mental and physical 24 health and are experienced widely across the world in vastly different ways associated with social values 25 (Tschakert et al., 2019). There are respectable arguments for the case that all life has intrinsic value 26 (Vetlesen, 2019). The NELD framing of climate impacts highlights that not all risks are measurable. While 27 difficult to measure, there are a growing number of cases of non-economic loss and damage globally 28 (medium evidence, high agreement). Illustrative examples of non-economic loss and damage from climate 29 change include the Pacific (McNamara et al., 2021b) and Small Island Developing States (SIDS) in the 30 Caribbean. (Martyr-Koller et al., 2021). For example, the hurricane season in 2017 was particularly extreme 31 resulting in climate-induced displacement with direct implications for non-economic loss and damage, 32 including threats to health and wellbeing and loss of culture and agency (Thomas and Benjamin, 2020). | 1522 - 152 | Impact | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 33 34 In the context of the Pacific Islands NELDs are thought of as interconnected and span human mobility and 35 territory, cultural heritage and Indigenous Knowledge, life and health, biodiversity and ecosystem services, 36 and sense of place and social cohesion (Carmona et al., 2017; Ojwang et al., 2017; McNamara et al., 2021b). | 1522 - 1522 | | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 49 50 In order to categorise the different types of non-economic loss and damage that exist (Serdeczny et al., 51 2016), based on their literature review, the authors come up with a set of systematic categories that capture 52 what is usually thought about as having intrinsic value and according this framing of non-economic loss and 53 damage this includes: human life, sense of place and mobility, cultural artefacts, biodiversity and 54 ecosystems, communal and production sites and agency and identity (Serdeczny et al., 2016; Serdeczny, 55 2019). For example, there is emerging evidence on linkages between slow onset events and mobility 56 decisions, trajectories and outcomes (Zickgraf, 2021). In addition, categories include psychosocial and 57 emotional distress (van Der Geest and Schindler, 2016). For example, research shows potential increased ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 8 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 8-48 Total pages: 155 1 risk of Intimate Partner Violence (IPV) following disasters, noting that societies that are vulnerable to 2 climate change may need to prepare for the social disasters that can accompany disasters revealed by natural 3 hazards (Malik and Stolove, 2017; Rai et al., 2021). | 1522 - 152 | Impact | INTANBILE | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 7 Key groups affected include low income groups, agropastoralists, women and girls, children and youth, 8 Indigenous Peoples, ethnic and religious minorities. In Europe, the Samis who as a group face significant 9 challenges to health as ecosystems deteriorate (Jaakkola et al., 2018). In Africa, In Zimbabwe storm Idai 10 affected 270,000 people and subsequent flooding and landslides left 340 people dead and many others 11 missing (Chanza et al., 2020). There is evidence of loss of cultural heritage sites where effects of sea-level 12 rise and coastal erosion, the other considering climate change and variability (Brooks et al., 2020). Haile et 13 al. (2013) show flood casualties in Ethiopia include children drowned while playing outside during the 2007 14 flood period although official data is hard to come by (p. 489). Moreover, loss of place was experienced 15 when many of local houses in Itang built from wood, grasses and mud walls, which are easy to reconstruct 16 building economics are not strong enough to withstand an extreme flood and 38% of the surveyed houses 17 were severely damaged by the 2007 flood. These houses were constructed as an adaptation strategy but could 18 not withstand the floods. In Kenya, Opondo (2013) shows loss of human life was the most severe impact of 19 floods. For example, in the focus group discussion with men, 'it was reported that a boat capsized on River 20 Nzoia at Siginga and ten people died'. (p. 457). In Mozambique, Brida et al. (2013) show loss of sense of 21 place occurred after flooding in the central districts of Caia and Mopeia, flooding had a devastating impact 22 on homes and livestock (Brida et al., 2013). Health impacts of the forest fire impacts in Amazon basin 23 countries have disproportionately affected vulnerable people/social groups (see Box 8.6). | 1523 - 152 | 'rot-Adapt-Mitig-Impact | | INDG |
| IPCC_AR6_WGII_Full_Report | 5 6 8.3.5 Economic and non-economic losses and damages due to climate change and their implications for 7 livelihoods and livelihood shifts 8 9 This section examines the intersections between losses and damages and livelihood shifts. This requires an 10 examination of the differentiated aspects of livelihoods. Understanding economic (e.g., loss of food crops, 11 infrastructure, assets etc.) and non-economic losses (e.g., health, wellbeing, loss of place, agency) and their 12 consequences for livelihoods is important that the intangible aspects clearly become visible and to receive 13 greater attention in loss assessments and in designing adaptation strategies and programmes. Figure 8.10 14 provides a summary of examples of observed impacts of climate hazards on economic and non-economic 15 capitals and the section assesses livelihood implications across regions. It shows examples of climate hazards 16 attributed to climate change in studies since AR5, across a range of geographical sites for heatwaves, 17 drought, hurricanes, and floods and non-economic losses and damages. The figure 8.10 reveals examples of 18 climate hazards attributed to climate change in studies since AR5 across a range of geographical sites for 19 extreme and slow onset events, such as heatwaves, drought, hurricanes and sea level rise. These are 20 associated with non-economic losses and damages. These figure underscores that non-economic losses and 21 damages lead to significant livelihood threats and livelihood changes. Also limits of adaptation become 22 evident (Chapter 16). | 1524 - 152 | 'rot-Adapt-Mitig-Impac | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 40 41 In Central Asia, the Sahel and South Asia, three global poverty hotspots, change impacts were shown to 42 undermine traditional knowledge about livelihoods in ways that jeopardise future culture cohesion and sense 43 of place (Tucker et al., 2015). Acosta et al. (2016) identified loss to productive sites in the Philippines with 44 landslides destroying agriculture leaving many farmers without livelihoods. Similarly, Beckman and Nguyen 45 (2016) in Vietnam identified an example where communal dams had been destroyed in floods leading to lack 46 of irrigation for communal sites and local loss of farmland for farming communities. Chandra et al. (2017) 47 identified the vicious cycle between declining agricultural production and conditions of soil erosion due to 48 floods and droughts resulting in decreased crop fertility to productive sites with implications for decline in 49 crop yields, loss of crops and of livelihood assets. Climate change related extreme weather events such as 50 typhoons, floods, and droughts can have detrimental impacts on crop production (high confidence) and in the 51 Philippines and Pakistan have significantly affected the livelihoods of cash crop focused rural villages 52 (Escarcha et al., 2020; Jamshed et al., 2020b). There is an emerging shift from crop to livestock production 53 as a buffer activity to recover from crop losses (Section 5.10.4; Jamshed et al., 2017; Escarcha et al., 2020). | 1526 - 152 | Impact | INTANBILE | |

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| IPCC_AR6_WGII_Full_Report | 13 14 Research from Australia shows complex linkages between the impacts of drought on livelihood income, 15 health and cultural heritage, increasing risk of heat stroke, and possibly a link to suicide among male farmers 16 (Alston, 2012; Hanigan et al., 2012; Marshall et al., 2019). The link between agricultural losses and suicides 17 has also been noted in South Asia, including India (Carleton, 2017). Livelihoods are shifting with impacts to 18 wellbeing, as noted by (Evans et al., 2016) showing connections between loss of fishery productivity and 19 impact on tourism sector livelihoods in the Great Barrier Reef region. In Europe, losses to Indigenous 20 Peoples are associated with loss of wellbeing of Sami communities and has forced livelihood shifts from 21 reindeer herding due to loss of ecosystems to support the animals (Persson et al., 2017; Jaakkola et al., 22 2018). Traditional pastoralist systems are also greatly impacted by cumulative dual challenges of 23 encroachments of other land users and by climate change. Traditional Sami reindeer herding strategies are 24 still practiced, but that rapidly changing environmental circumstances are forcing herders into uncharted 25 territories where traditional strategies and the transmission of knowledge between generations may be of 26 limited use. For example, rotational grazing is no longer possible as all pastures are being used, and changes 27 in climate result in unpredictable weather patterns unknown to earlier generations (Axelsson-Linkowski et 28 al., 2020). These examples show that there are complex factors underpinning the linking loss and damage 29 and shifting livelihoods. Moreover, there are significant challenges to undertake a shift and secure alternative 30 livelihoods. | 1527 - 152 | Impact | | INDG |
| IPCC_AR6_WGII_Full_Report | 31 32 Linkages between losses, coping strategies and livelihood shifts in Small Islands (e.g., in the Pacific region 33 Kiribati and Tuvalu, and in the Caribbean the Bahamas) shed light on impacted low-income households. For 34 example, farmers have experienced extensive damage to homes and loss of infrastructure, and experience 35 lack of migration opportunities (Curtain and Dornan, 2019). Evidence is growing that there is also significant 36 loss of cultural heritage in resettlement (Barnett and O'neill, 2012), evidence from Small Islands displaced 37 communities suggests that resettlement can have impacts on sense of place, identity and social fabric, a 38 theme highly relevant to loss, coping and adapting livelihoods, and not only restricted to Small Islands 39 (McNamara et al., 2021b). Roberts (2015) identified loss of communal sites in Kiribati and it is predicted 40 that by 2050 up to 80% of the land on the island of Buariki and 50% of the land on Bikenibeu may be 41 completely inundated and these effects will result in significant loss of livelihoods and displacement. | 1527 - 152 | ʼrot-Adapt-Mitig-Impa | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 51 Across Peru, findings demonstrate that people use temporary and permanent migration among their many 52 coping and adaptation strategies. Hazards related to water excess have been the key force in destroying 53 homes and driving displacement in Peru. On the flipside, studies demonstrate that water scarcity also 54 threatens livelihoods and thereby influences migration in Peru. While non-climatic reasons for moving 55 dominate migrants' motivations in many areas of Peru, water-related climatic drivers of migration are 56 becoming increasingly relevant (Wrathall et al., 2014). Peru's smallholder farmers and urban poor are not 57 responsible for the climate crisis, yet their lives and cultural heritage are being increasingly jeopardized by ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 8 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 8-53 Total pages: 155 1 its effects, making improvements in governance an imperative for Peru (Bergmann et al., 2021). Another 2 area of significance is coffee production in Brazil where the majority of Brazilian coffee farms are operated 3 by smallholders, producers with relatively small properties and mostly reliant on family labour (Koh et al., 4 2020). In the United States (e.g., New Orleans and Puerto Rico) people have lost livelihoods due to displaced 5 households, destroyed homes, and led to loss of income as well as loss of social networks and family 6 networks and loss of cultural heritage. For example, impacts of Hurricane Katrina have led to people being 7 displaced from their employment, many evacuees had to relocate to new areas, which disrupted their social 8 networks and placed them in unfamiliar labour markets, resulting in mental health challenges (Palinkas, 9 2020). There has also been a 'climate gentrification' in parts of New Orleans (Aune et al., 2020). Many of 10 those who returned to their pre-Katrina areas had to deal with extensive damage to their homes and to public 11 infrastructure. | 1527 - 152 | ʼrot-Adapt-Mitig-Impact | | |

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| IPCC_AR6_WGII_Full_Report | 57 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 8 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 8-54 Total pages: 155 1 These 'climate gating' actions, such as drilling boreholes, secured water access for high-income households 2 and companies, but excluded a large proportion of Cape Town's population who could not afford such 3 private technologies (Simpson et al., 2019a; Simpson et al., 2020b). These responses were unanticipated by 4 the city administration and compounded fiscal challenges faced by the municipality which could no longer 5 use revenues from high-consumption households to cross-subsidise water for low-income households 6 (Simpson et al., 2020a). This shift threatened to undermine the sustainability of the municipal fiscus and 7 general water access ( Box 9.8; Simpson et al., 2019a; Simpson et al., 2020a). In order to recover losses, 8 municipal water tariffs for consumers were raised by 26% in 2018 (Muller, 2018; Simpson et al., 2019a). In 9 addition to decline in tourism, median estimations of the overall economic impact of the drought indicate 10 loss of 27.6 billion South African Rand (US$1.7 billion) translating into 64,810 job losses in the Western 11 Cape, with Cape Town accounting for approximately half of those job losses (DEDAT, 2018). This had a 12 disproportionate impact on unskilled and semi-skilled workers, particularly for those from low- and middle- 13 income households (DEDAT, 2018). The drought also exacerbated the potential for sanitation health risks of 14 the urban poor where tens of thousands of people lack access to safely managed sanitation facilities (Enqvist 15 and Ziervogel, 2019). | 1528 - 152 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 50 51 8.4.3 The influence of climate change responses on projected development pathways 52 53 Responses to climate change can have dual effects on development pathways. On the one hand, mitigation 54 and adaptation processes can create significant development opportunities. The potential of mitigation 55 policies for jobs creation, in particular, has been highlighted (Healy and Barry, 2017). However, responses to 56 climate change can also have detrimental effects on future development: mitigation policies such as the 57 building of hydro-electrical dams or the culture of biofuels can lead to communities' dislocation and ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 8 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 8-58 Total pages: 155 1 populations' resettlement, particularly of disadvantaged groups within a society (de Sherbinin et al., 2011; 2 Eriksen et al., 2021). Adaptation policies can also hinder some development processes: for example, the 3 promotion of migration as an adaptation strategy can lead to communities being deprived of their workforce, 4 and resenting the departure of some of their members (Gemenne and Blocher, 2017), even though they may 5 offer new livelihood opportunities. However, the migration consequences in the context of climate change 6 are often more nuanced and different trade-offs and benefits occur (see Porst and Sakdapolrak, 2020). For 7 example, remittances support family members, at the same time in some cases these can also create 8 imbalances in local markets (Melde et al., 2017). Evidence exists that some climate responses such as small- 9 scale agricultural livelihood adaptation strategies have improved the ability of people to sustain their 10 livelihood and to reduce poverty (Osbahr et al., 2010). | 1532 - 153 | Prot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGII_Full_Report | 36 37 8.4.5 Projected risks for livelihoods and consequences for equity and sustainability 38 39 8.4.5.1 Projected risks for livelihoods 40 41 There is robust evidence with high agreement that future climate change impacts will have severe 42 consequences for poor households, particularly those situated in areas highly exposed to actual or future 43 climate hazards, such as low lying coastal communities (see also Cross-Chapter Paper 1 COASTS), drylands 44 (see also Cross-Chapter Paper 3 DRYLANDS) or remote mountain (see also Cross-Chapter Paper 5 45 MOUNTAINS) settlements with low levels of connectivity to markets, poor infrastructure and high 46 dependence upon poor quality natural capital (Barbier and Hochard, 2018; Gioli et al., 2019). While 47 livelihoods operate in a dynamic context characterised by multiple interacting structures and processes, 48 climate change can act as a risk multiplier. When current livelihood activities become untenable as a result of 49 both long trends and short-term shocks and climate hazards (e.g., droughts, floods), shifting livelihoods is a 50 common response and in many cases can be unavoidable due to the negative consequences of these climate 51 hazards on specific livelihood capitals (see Section 8.5). Such shifts can involve a change in livelihood 52 activities (e.g., continuing in agriculture but growing different kinds of crops), or a change to broader 53 livelihood strategies (e.g., diversifying into handicrafts or paid employment, specialising in one particular 54 activity, or migrating, seasonally or permanently in search of other livelihood opportunities) or even an 55 entire change of the livelihood activity, for example, abandoning agriculture altogether (McLeman and Smit, 56 2006; Black et al., 2011). Shifting livelihoods can therefore involve mobility or take place in situ. Some of 57 these shifts also lead to social tipping points. | 1534 - 153 | Impact | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 15 16 In the Arctic, temperature warming, and sea level rising constitute a key risk to the loss of identity and 17 culture of Indigenous People, associated to migration and or relocation due to livelihoods deterioration from 18 coastal erosion, permafrost thaw, and reduced fisheries productivity (Roberts and Andrei, 2015; Roy et al., 19 2018). These risks and losses often encompass various non-economic losses, such as the loss of identity that 20 cannot be replaced or economically compensated (see also Section 8.3.5). | 1539 - 153 | Impact | | INDG |
| IPCC_AR6_WGII_Full_Report | 33 34 The glacier retreat associated with the increase in global warming temperature has also shown losses that are 35 permanent and related to a sense of belonging and cultural heritage for the Glacier countries but with the 36 most negative livelihood impacts experienced among poor households in the Peruvian Andes and Himalayas 37 (Jurt et al., 2015). The risks for the glacier smallholder's livelihoods are expected to increase in the future 38 once the shrinking glaciers are expected to increase water competition, crop failure, and extreme flooding 39 (Kraaijenbrink et al., 2017). For example, in Bhutan adaptive measures such as changing crops, developing 40 irrigation channels, and sharing water among the community members still insufficient to avoid loss and 41 damage associated with the dramatically reduced water availability (Kusters and Wangdi, 2013; Warner and 42 Van der Geest, 2013). In high Mountain Regions, the intersections of agro-pastoralists marginalization, 43 difficult in access, and ecological sensitivity contribute to residual impacts associated with extreme climate 44 hazards which can lead to irreversible losses and challenge poverty reduction efforts (Mishra et al., 2019). | 1539 - 153 | ?rot-Adapt-Mitig-Impa | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 42 43 Fires are not a natural phenomenon in the Amazon region (Bush et al., 2004; McMichael et al., 2012) albeit 44 used for food security, hunting and religious rituals among Indigenous Peoples and traditional communities 45 (Hecht, 2006; Carmenta et al., 2019; da Cunha, 2020), and also as a widespread technique for land clearing 46 for small and large-scale farms for agriculture (Morello et al., 2019). The dramatically increased forest 47 burning observed in the Amazon recently are the results of illegal land grabbing, the small and large-scale 48 cattle ranching sector and agribusiness practices coupled with loosening land tenure policies and decision 49 making neglect of deforestation and burning monitoring data (Nobre et al., 2016; Lovejoy and Nobre, 2018; 50 Leal Filho et al., 2020a). The fire outbreaks intensified substantially to the point that in August 2019 there 51 were approximately 3500 fires in 148 Indigenous territories (DETER and INPE, 2019; ISA, 2019). Although 52 most of the burning in the Legal Amazon in Brazil occurred on private land of medium and larger sizes 53 (about 67%), around 33% was observed within Indigenous territories and protected areas called conservation 54 units (UCs) (DETER and INPE, 2019; ISA, 2019). In 2019, 40% of the deforestation occurred in public 55 forests, which encompasses undesignated forest lands, Indigenous territories and conservation units (UCs). | 1540 - 154 | Prot-Adapt-Mitig- | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 23 24 In the Acre State, the fire incidence coupled with extreme droughts in 2005 and 2010 led to an increase— 25 from 1.2% to 27%—in hospitalizations of children (under 5 years) due to respiratory diseases (Smith et al., 26 2015). The same evidence was found among the rapidly deforested areas known as 'Arc of Deforestation' 27 that have dramatically led to a higher number of respiratory diseases mainly in children under 5 years (do 28 Carmo et al., 2013). There is also evidence for interlinked dynamics between deforestation, urbanization and 29 incidence of fire episodes providing an appropriate environment for Anopheles darlingi vector propagation 30 and the increased incidence of malaria in the region (Hahn et al., 2014). In the 2005 drought, burning in Acre 31 alone recorded 400,000 people affected and the loss of 300,000 hectares of forest with direct costs of US$50 32 million (Brown et al., 2006). In 2010, the fires during the drought were approximately 16 times larger than 33 that in the meteorologically normal years (Campanharo et al., 2019). The estimated total economic loss in 34 2010 was about US$243.36 ± 85.05 million, representing 9.07 ± 2.46% of Acre's gross domestic product 35 (GDP) (Campanharo et al., 2019). The economic and non-economic losses associated with the impacts of 36 climate change and future risks of fires outbreaks on native food crops (açai, guaraná), livelihoods, tourism, 37 medicinal and spiritual sites, culture, migration patterns, place-based attachments, emotional and mental 38 distress among the most affected and vulnerable population as Indigenous Peoples and traditional 39 communities are still to be fully estimated for the region (Pinho et al., 2015; Brondízio et al., 2016). Also 40 relevant is a trend of Amazonian forest fires spreading from the southern Brazilian Amazon to Bolivia and 41 Peru, indicating that transboundary burning increases are systemic and will lead to extensive economic 42 losses of wildcrops, infrastructure and livelihoods, and requiring a landscape level approach for deforestation 43 and fire management and control (Kalamandeen et al., 2018). | 1541 - 154 | Impact | INTANBILE | INDG |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 26 27 Table 8.6, built from SR1.5°C (Roy et al., 2018), illustrates how ecological thresholds and socio-economic 28 determinants are linked to soft and hard adaptation limits and what are the potential and magnitude of 29 livelihoods risks in the future. For instance, in the SR1.5°C (IPCC, 2018b) and SROCC (IPCC, 2019b), hard 30 limits are expected with global warming beyond 1.5°C associated with the losses of coral reefs, that will lead 31 to substantial loss of income and livelihoods for coastal communities (Roy et al., 2018; Mechler et al., 32 2019b; Oppenheimer et al., 2019). The loss of coral reefs in remote islands of Boigu in Australia are 33 affecting low-lying communities facing financial, institutional (Evans et al., 2016) and cultural place-based 34 attachment adaptation limits (McNamara et al., 2017). Another hard limit to adaptation and implications for 35 income, and culture-and place-based livelihoods is related to the sensitivity of global fish to global 36 temperature increase with losses of fish reproduction expected to 10% (SSP1–1.9) to about 60% (SSP5–8.5) 37 potentially cascading into severe risks for fisheries livelihoods (Dahlke et al., 2020). In West African 38 fisheries, the loss of coastal ecosystems and productivity are estimated to require 5–10% of countries' gross 39 domestic product (GDP) in adaptation costs (Zougmoré et al., 2016), incurring financial limits in the poor 40 countries to avoid socio-economic risks. The SROCC (IPCC, 2019b) showed that scientific knowledge 41 limitations can constrain management of coastlines, mainly in the context of lack of data with affect most of 42 the vulnerable and poor communities in the global south (Perkins et al., 2015; Sutton-Grier et al., 2015; 43 Wigand et al., 2017; Romañach et al., 2018). The hard and soft adaptation limits are challenging to be 44 defined, given the rate and intensity of climate change hazards and the mitigation and adaptation options 45 available, but also the level and rate of non-climatic stresses increasing vulnerabilities and undermining 46 adaptive capacity of poorest members of society and sensitive ecosystems (medium evidence, high 47 agreement) (Klein et al., 2014; Roy et al., 2018). | 1544 - 154 | 'rot-Adapt-Mitig-Impa | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 1.5°C; Chapter 3, Box 3.5 (Hoegh-Guldberg et al., 2018); Chapter 4, Cross�chapter Box 4.1 (de Coninck et al., 2018)); The projected SLR is projected to affect human health and wellbeing, cultural and natural heritage, freshwater, biodiversity, agriculture, and fisheries (IPCC, 2018b; WHO, 2018; IDMC, 2019; McMichael et al., 2020). | 1547 - 1547 | | | |
| IPCC_AR6_WGII_Full_Report | 1 2 3 8.4.5.7 Compounding future risks on equity and sustainability 4 5 The compounding future effects on equity and sustainability emerge when multiple stressors linked to 6 environmental and/or climate change, together with underlying structural poverty, exclusion, 7 marginalization, and conflicts creating risks that need to be addressed simultaneously. Compounding risks of 8 climate change received attention in AR5 (Oppenheimer et al., 2014) including risks associated with 9 compound hazards (O'Neill et al., 2017b), and their implications for future risk when repeated impacts erode 10 human and ecosystem capacity, including through transboundary effects. In SRCCL (IPCC, 2019a), land 11 degradation and climate change compounded to highly expose the livelihoods of the poor to climate hazards 12 and caused food insecurity (high confidence), migration, conflict and loss of cultural heritage (low 13 confidence) (Olsson et al., 2019). | 1548 - 154 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 25 26 Climate change affects people inequitably, and everyone does not contribute equally to climate change. A 27 range of economic and non-economic impacts can be experienced. This has led some researchers to call for a 28 more central role for rights-based approaches to adaptation, to help secure space for those marginalised from 29 adaptation decision making and to prioritise access to resources and information for those most vulnerable 30 to, or affected by, the social, cultural or economic consequences of climate change (Bee et al., 2013; Da 31 Costa, 2014; Toussaint and Martinez Blanco, 2020; Box 8.7; Section 5.12). In terms of international law, the 32 human rights obligations of states have been subject to multiple recommendations relating to climate change 33 by UN treaty bodies in the reporting period. More broadly, rights-based approaches rely on the normative 34 framework of human rights, requiring adaptation to be non-discriminatory, participatory, transparent and 35 accountable in both formal (e.g., legal and regulatory) and informal (e.g., social or cultural norms) settings 36 and at international, national and sub-national scales (Ensor et al., 2015; Arts, 2017). Sovacool et al. (2015) 37 note that unless critical competing interests are addressed during planning, adaptations may fail to achieve 38 the desired outcomes. This is increasingly seen at a political level within efforts to implement the Paris 39 Agreement, in relation to the principle of 'Common but Differentiated Responsibilities and Respective 40 Capacities' (CBDR-RC) (Box 8.7). | 1552 - 155 | 'rot-Adapt-Mitig-Impa | INTANBILE | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 52 53 There is broad support for the notion, enshrined in the Paris Agreement, that adaptation finance flowing to 54 developing countries of the Global South should primarily benefit the most climate-vulnerable among them 55 due to their limited technical capacity and financial capabilities, yet such countries are often insufficiently 56 considered in funding decisions. There are nevertheless concerns regarding institutional fit: that foreign 57 funding regimes may not map onto more recently developed administrative traditions, leading to dominance ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 8 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 8-81 Total pages: 155 1 of governance models emanating from donors (Vink and Schouten, 2018). Research has found multilateral 2 donors do not prioritise vulnerable developing countries at the project selection stage and they have received 3 smaller allocations of adaptation finance from bilateral donors than less vulnerable countries (Saunders, 4 2019), leaving the poor vulnerable to climate impacts. The lack of climate finance flowing to LDCs and 5 SIDs (currently 14 and two percent of the total, respectively) is compounded by access issues due to the 6 inability of domestic institutions to meet specific fiduciary standards and other access requirements, 7 insufficient human resource support and the inflexibility of current approaches which are biased in favour of 8 governments and against non-traditional actors such as local enterprise and grassroots organisations (Shakya 9 et al., 2021). Further, vulnerable developing countries shoulder additional financial burden, embodied in 10 higher interest payments to service public and private debt, due to the increased cost of capital brought about 11 by greater exposure to climate risks (Buhr et al., 2018). This has been further exacerbated by the recession 12 and debt distress accompanying the Covid-19 pandemic (Kose et al., 2021). A range of reforms, including 13 comprehensive debt relief by public creditors, green recovery bonds, debt-for-climate swaps and new SDG- 14 aligned debt instruments may address unsustainable debt burdens, freeing up investment in climate 15 adaptation and a green economic recovery (Volz et al., 2020; see Section 8.6.3.1).. | 1555 - 155 | Prot-Adapt-Mitig-Impac | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 30 31 Policies and investments that are adopted are embedded within the relevant legal and regulatory frameworks, 32 which extend beyond national jurisdictions upward to the regional scale (such as the Southern Africa 33 Development Community's Southern Africa Regional Framework of Climate Change Programmes, (2010)) 34 and international scale, for example, UNFCCC, the 2015 Paris Agreement, the Sendai Framework for 35 Disaster Risk Reduction, the New Urban Agenda and the SDGs. Legal and regulatory concerns also extend 36 downward to shape local- and city-scale adaptation efforts (e.g., Sao Paulo's municipal policy and new 37 master plan). Nevertheless, only a minority of countries have dedicated legal frameworks supporting 38 adaptation (Lesnikowski et al., 2017) and these often lack in both precision and obligation—largely because 39 adaptation is a contested global public good but also because adaptation is commonly bundled in with 40 mitigation commitments (Hall and Persson, 2018). Coherence, horizontally and vertically in both policy and 41 law is often lacking. At the same time, bottom-up, private, autonomous adaptation efforts are being better 42 tracked, with different actors motivated by growing experiences of local climate change impacts (Berrang- 43 Ford et al., 2014).While the emergent polycentricity of adaptation governance is beginning to take shape, 44 wherein both state and non-state actors share a common adaptation goal and interact coherently, yet often 45 independently, to advance progress towards it (Morrison et al., 2019), understandings of how various centres 46 of decision making with different degrees of autonomy support an enabling environment for adaptation, 47 remain at a nascent stage . Multiple scales and forms of adaptation occur, with attributes such as self- 48 organisation, appreciation of site-specific conditions, and the need for learning and experimentation, 49 alongside building of trust, increasingly shown to be vital (Dorsch and Flachsland, 2017). Literature 50 indicates that professional and learning networks are important groups supporting adaptation in cities and 51 can help harness resources (Woodruff, 2018); while (Hauge et al., 2019) research in Norway underscores the 52 importance of working across multiple disciplines and the inclusion of actors from different levels of 53 authority in multilevel municipal networks. They found that these factors can help to identify specific 54 adaptation actions as well support knowledge sharing within participating organisations, which in turn helps 55 garner commitment to adaptation and its implementation. They also found that it is important to involve 56 local leaders in polycentric adaptation networks. | 1556 - 155 | Prot-Adapt-Mitig-Impac | | |

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| IPCC_AR6_WGII_Full_Report | 2 Indigenous Knowledge systems as they are embedded in culture, and are passed from generation to 3 generation in various ways: livelihoods, traditions, spiritual practices and oral tradition, cultural identity, and 4 historical memory. Indigenous Knowledge is known or learnt from experience, or acquired through 5 observation and practice, and handed down from generation to generation. It is acknowledged that 6 Indigenous Peoples communities, particularly those in hazard-prone areas, have developed a profound 7 understanding and knowledge of disaster prevention and mitigation, early warning, preparedness and 8 response, and post disaster recovery. While Indigenous Knowledge systems, themselves, are an 9 indispensable dimension of capacity for adaptation, and where threatened represent a major risk to 10 Indigenous Peoples communities. While still robust among Indigenous Peoples in many parts of Africa, Asia 11 and Latin America, Indigenous Knowledge is not well reflected or incorporated in assessments such as this, 12 and stands in danger of being lost as its custodians are passing away. | 1560 - 156 | 'rot-Adapt-Mitig-Impa | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 51 52 53 Table Box 8.8.1: Coping and adaptation actions enacted in the cyclone Aila affected area in response to losses of and 54 damage to physical capital Coping and adaptation actions Action group References ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 8 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 8-87 Total pages: 155 Human migration—mostly forced due to loss of houses as well as other resources and livelihood activities Households (Abdullah et al., 2016; Mallick et al., 2017; Paul and Chatterjee, 2019) Alternative livelihood activities such as crafts, and honey and wood collection from the Sundarbans, due to irreparable damage to fishing gear Households (Alam et al., 2015) Saving money for house repairs or construction Households (Alam et al., 2015) Underground storage of emergency items such as foods, matchbox, cooker and cooking fuel Households (Alam et al., 2015) Selection of high land to build shelter along both sides of the embankments Households (Alam et al., 2015) Tree plantation in the homestead periphery to protect the house from gusty winds and to use as a source of wood for house repair/construction Households (Alam et al., 2015) Increasing height of the house plinth Households (Alam et al., 2015) Changing of house roofing material from thatched to corrugated iron sheet or asbestos Households (Alam et al., 2015) Informally allowing people to harvest Sundarbans forest wood without any charge so they could make makeshift houses Forest Department (Abdullah et al., 2016) Rainwater harvesting using plastic or clay pots and artificial aquifer tube-wells for securing drinking water. | 1561 - 156 | 'rot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | 24 25 Similarly, technology must always be grounded in an appreciation of the cultural context. Research in the 26 European Arctic with the Indigenous Sami Peoples found that use of GPS technology on reindeer, together 27 with supplementary feeding, offer useful adaptations for some herders. However, there are fears such 28 technologies may, over time, reduce the skills, cultural knowledge and Indigenous adaptations of the Sami 29 (Andersson and Keskitalo, 2017), as, for example, reindeer become more tame through supplementary 30 feeding, affecting their range selection. Overall, technology and other adaptations should seek not to erode 31 Sami culture's adaptive capacity (Vuojala-Magga et al., 2011; Risvoll and Hovelsrud, 2016), particularly 32 because reindeer grazing as a land management practice can play a useful climate change mitigation role too. | 1563 - 156 | Prot-Adapt-Mitig- | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 22 Funds were raised from households through donations via a self-imposed sales tax. While this example 23 paints a positive picture of the role of social capital and collective action in adaptation activities, it also raises 24 questions about the coherence of actions across levels, again, highlighting a role for polycentric governance 25 if risks of maladaptation are to be reduced. The danger in the example presented here is that should federal 26 plans in future conflict with the community level work, local efforts may have been in vain if installations 27 have to be removed. This highlights the importance of careful evaluation of all adaptation options on an 28 ongoing basis. | 1564 - 156 | 'rot-Adapt-Mitig-Impa | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 39 40 Potential opportunities from CSA may also result from Integration of "technological packages" (Totin et al., 41 2018), which include new market structures; knowledge infrastructure and agriculture extension services; 42 and capacity building programs (Dougill et al., 2017; Totin et al., 2018); institutional support for key 43 enabling programs, such as crop insurance, agro-advisories and rainwater harvesting (Khatri-Chhetri et al., 44 2017). CSA is able—if carefully designed—to achieve transformative "triple wins" for climate and 45 development when it is accompanied by new governance architectures that are socially inclusive and 46 respectful of traditions and livelihoods, and accommodate traditional institutions that underpin the 47 bargaining power of the poorest and most vulnerable groups (Karlsson et al., 2017). | 1570 - 1570 | | INTANBILE | |

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| IPCC_AR6_WGII_Full_Report | 47 48 Policies supporting sustainable rangeland management and the livelihood strategies of rangeland users have 49 an outsized influence on both development and climate action (Gharibvand et al., 2015). Climate change 50 adaptation, mitigation practices and livestock production can be supported by policies that encourage 51 diversification of livestock animals (within species), support sustainable foraging and feed varieties (Rivera- 52 Ferre et al., 2016), strengthen institutions such as agricultural support programs, markets and intra- and inter- 53 regional trade (Zhang et al., 2017). For example, sustainable pastoralism can contribute to mitigation both by 54 increasing carbon sequestration through improved soil management and by reducing methane emissions 55 through changing the mix and distribution of the herd. Likewise sustainable pastoralism can also contribute 56 to adaptation by changing grazing management, introducing alternative livestock breeds, pest management, 57 and modified production structures (Joyce et al., 2013). Another example of rangeland adaptation is ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 8 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 8-97 Total pages: 155 1 diversifying the use of rangelands such as supplementing with payments for ecosystem services, carbon 2 sequestration, tourism or supplementary assistance for all land based activities (Gharibvand et al., 2015). | 1571 - 157 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | 12 13 This chapter builds from AR5 and 1.5°C Report on key limits to the adaptation of natural and social systems 14 since that are compounded by the effects of poverty and inequality such as on water scarcity, ecosystems 15 alteration and degradation, coastal cities in relation to sea-level rise, cyclones and coastal erosion, food 16 systems and human health (high confidence). The climate change risks substantially pose negative impacts 17 on climate-sensitive livelihoods of smallholder farmers, fisheries communities, Indigenous People, urban 18 poor, informal settlements, with limits to adaptation evidenced on the loss income, ecosystems, health, and 19 increasing migration (high confidence). It also addresses how ecological thresholds and socio-economic 20 determinants of vulnerabilities are linked to soft and hard adaptation limits, including the potential and 21 magnitude to livelihoods risks in the future. For instance, a hard limit associated to losses of coral reefs at 22 1.5°C warmer world will lead to substantial loss of income and livelihoods for coastal communities (high 23 confidence), including loss of culture and place-based attachment (medium confidence). The adaptation hard 24 limits are expected for the Arctic ecosystem, whose threshold will affect residents of Arctic regions 25 dependent on hunting and fishing livelihoods (high confidence). New emerging considerations to ecological 26 limits to adaptation such as severe glacier retreat and Amazon Forest dieback, is expected to affect the 27 livelihoods of smallholder's farmers, and Indigenous People through crops yield failures, biodiversity loss, 28 reduced hydropower capacity and heath (medium evidence). While a knowledge gap remains on the 29 projected risks of increasing global temperature to climate-sensitive livelihoods among global south 30 countries and specific groups of people, current observations show negative impacts to livelihoods for tens to 31 hundreds of millions of people. Thus, without sustainable, equitable and urgent adaptation measures, 32 maladaptation risks are likely to further increase vulnerability, marginalization, and ecological tipping points 33 among the poor within countries (medium confidence). | 1581 - 158 | ›rot-Adapt-Mitig-Impa‹ | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 34 35 Evidence on the kinds of enabling environment required paints a complex picture. The assessment highlights 36 the interaction of different capital assets with the broader context of key enablers in shaping the overall 37 enabling environment for adaptation, which itself is highly context-dependent. In this regard, countries 38 present different starting points for adaptation, with some requiring, for example, more of an emphasis on 39 institutional capacity building; others requiring transformation to the broader legal and political conditions. | 1581 - 158 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 8 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 8-117 Total pages: 155 1 Bryant, L. and B. Garnham, 2015: The fallen hero: masculinity, shame and farmer suicide in Australia. Gender, Place 2 & Culture, 22(1), 67-82, doi:https://doi.org/10.1080/0966369X.2013.855628. | 1591 - 1592 | | | |
| IPCC_AR6_WGII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 8 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 8-120 Total pages: 155 1 Crate, S. A., 2011: Climate and culture: anthropology in the era of contemporary climate change. Annual Review of 2 Anthropology, 40, 175-194, doi:10.1146/annurev.anthro.012809.104925. | 1594 - 1595 | | | |

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| IPCC_AR6_WGII_Full_Report | 7 {9.5.3–7, 9.7} 8 9 Glaciers on the Rwenzoris and Mt. Kenya are projected to disappear by 2030, and by 2040 on 10 Kilimanjaro (medium confidence). {9.5.8} 11 12 In East and southern Africa, tropical cyclones making landfall are projected to become less frequent 13 but have more intense rainfall and higher wind speeds at increasing global warming (medium 14 confidence). {9.5.7} 15 16 Heat waves on land, in lakes, and in the ocean will increase considerably in magnitude and duration 17 with increasing global warming (very high confidence). Under a 1.5°C-compatible scenario, children born 18 in Africa in 2020 are likely to be exposed to 4–8 times more heat waves compared to people born in 1960, 19 increasing to 5–10 times for 2.4°C global warming. The annual number of days above potentially lethal heat 20 thresholds reaches 50–150 in west Africa at 1.6°C global warming, 100–150 in Central Africa at 2.5°C, and 21 200–300 over tropical Africa for >4°C. {9.5.2, 9.5.3, 9.5.4, 9.5.5, 9.5.6, 9.7.2.1} 22 23 Most African countries will enter unprecedented high temperature climates earlier in this century 24 than generally wealthier, higher latitude countries, emphasising the urgency of adaptation measures in 25 Africa (high confidence). {9.5.1} 26 27 Compound risks 28 Multiple African countries are projected to face compounding risks from: reduced food production 29 across crops, livestock and fisheries; increasing heat-related mortality; heat-related loss of labour 30 productivity; and flooding from sea level rise, especially in West Africa (high confidence). {9.8.2, 9.8.5, 31 9.9.4, 9.10.2, 9.11.2} 32 33 Water 34 Recent extreme variability in rainfall and river discharge (c. -50% to +50% relative to long-term 35 historical means) across Africa have had largely negative and multi-sector impacts across water- 36 dependent sectors (high confidence) {9.7.2, 9.10.2}. Hydrological variability and water scarcity have 37 induced cascading impacts from water-supply provision and/or hydro-electric power production to health, 38 economies, tourism, food, disaster risk response capacity and increased inequality of water access. {Box 9.4} 39 40 Extreme hydrological variability is projected to progressively amplify under all climate scenarios 41 relative to the current baseline, depending on region (high confidence). Projections of numbers of people 42 exposed to water stress by the 2050s vary widely—decreases/increases by hundreds of millions, with higher 43 numbers for increases—with disagreement among global climate models the major factor driving these large 44 ranges. Populations in drylands are projected to more than double. Projected changes present heightened 45 cross-cutting risks to water-dependent sectors, and require planning under deep uncertainty for the wide 46 range of extremes expected in future. {9.7.1, 9.7.2} 47 48 Economy and Livelihoods 49 Climate change has reduced economic growth across Africa, increasing income inequality between 50 African countries and those in temperate, Northern Hemisphere climates (high confidence). One 51 estimate suggests GDP per capita for 1991–2010 in Africa was on average 13.6% lower compared to if 52 climate change had not occurred. Impacts manifest largely through losses in agriculture, as well as tourism, 53 manufacturing, and infrastructure. {9.6.3, 9.11.1} 54 55 Climate variability and change undermine educational attainment (high agreement, medium evidence). | 1636 - 163 | Prot-Adapt-Mitig-Impac | | |

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| IPCC_AR6_WGII _Full_Report | 40 Increased rainfall variability is expected to affect electricity prices in countries highly dependent on 41 hydropower. {9.9.4; Boxes 9.4, 9.5} 42 43 Ecosystems 44 Increasing CO2 levels and climate change are destroying marine biodiversity, reducing lake 45 productivity, and changing animal and vegetation distributions (high confidence). Impacts include 46 repeated mass coral bleaching events in east Africa, and uphill (birds) or poleward (marine species) shifts in 47 geographic distributions. For vegetation, the overall observed trend is woody plant expansion, particularly 48 into grasslands and savannas, reducing grazing land and water supplies. {9.6.1} 49 50 The outcome of interacting drivers operating in opposing directions on future biome distributions is 51 highly uncertain. Further increasing CO2 concentrations could increase woody plant cover, but increasing 52 aridity could counteract this, destabilising forest and peatland carbon stores in central Africa (low 53 confidence). {9.6.2.1} 54 55 African biodiversity loss is projected to be widespread and escalating with every 0.5ºC increase above 56 present-day global warming (high confidence). Above 1.5°C, half of assessed species are projected to lose 57 over 30% of their population or area of suitable habitat. At 2°C, 36% of freshwater fish species are ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 9 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 9-9 Total pages: 225 1 vulnerable to local extinction, 7–18% of species assessed are at risk of extinction, and over 90% of East 2 African coral reefs could be destroyed by bleaching. Above 2°C, risk of sudden and severe biodiversity 3 losses becomes widespread in West, Central and East Africa. Climate change is also projected to change 4 patterns of invasive species spread. {9.6.2} 5 6 Climate security 7 There is increasing evidence linking increased temperatures and drought to conflict risk in Africa 8 (high confidence). Agriculturally dependent and politically excluded groups are especially vulnerable to 9 drought-associated conflict risk. However, climate is one of many interacting risk factors, and may explain a 10 small share of total variation in conflict incidence. Ameliorating ethnic tensions, strengthening political 11 institutions, and investing in economic diversification could mitigate future impacts of climate change on 12 conflict. {Box 9.9} 13 14 Heritage 15 African cultural heritage is already at risk from climate hazards, including sea level rise and coastal 16 erosion. Most African heritage sites are neither prepared for, nor adapted to, future climate change 17 (high confidence). {9.12} 18 19 Adaptation 20 21 With global warming increasing above present-day levels the ability of adaptation responses to offset 22 risk is substantially reduced (high confidence). Crop yield losses, even after adaptation, are projected to 23 rise rapidly above 2°C global warming. Limits to adaptation are already being reached in coral reef 24 ecosystems. Immigration of species from elsewhere may partly compensate for local extinctions and/or lead 25 to local biodiversity gains in some regions. However, more African regions face net losses than net gains. At 26 1.5°C global warming, over 46% of localities face net losses in terrestrial vertebrate species richness with net 27 increases projected for under 15% of localities. {9.6.1.4, 9.6.2.2, 9.8.2.1, 9.8.2.2, 9.8.4} 28 29 Technological, institutional, and financing factors are major barriers to climate adaptation feasibility 30 in Africa (high confidence). {9.3, 9.4.1} 31 32 There is limited evidence for economic growth alone reducing climate damages, but under scenarios of 33 inclusive and sustainable development, millions fewer people in Africa will be pushed into extreme 34 poverty by climate change and negative impacts to health and livelihoods can be reduced by 2030 35 (medium | 1638 - 163 | ’rot-Adapt-Mitig-Impact | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 43 Nevertheless, social protection programs may increase resilience to climate-related shocks, even if they do 44 not specifically address climate risks. {9.4.2, 9.10.3, 9.11.4} 45 46 The diversity of African indigenous knowledge and local knowledge systems provide a rich foundation 47 for adaptation actions at local scales (high confidence). African indigenous knowledge systems are 48 exceptionally rich in ecosystem-specific knowledge used for management of climate variability. Integration 49 of indigenous knowledge systems within legal frameworks, and promotion of indigenous land tenure rights 50 can reduce vulnerability. {9.4.4; Box 9.1, Box 9.2} 51 52 Early warning systems based on targeted climate services can be effective for disaster risk reduction, 53 social protection programmes, and managing risks to health and food systems (e.g., vector-borne 54 disease and crops) (high confidence). {9.4.5, 9.5.1, Box 9.2, 9.8.4, 9.8.5, 9.10.3, 9.11.4} 55 56 Risk-sensitive infrastructure delivery and equitable provision of basic services can reduce climate 57 risks and provide net financial savings (high confidence). However, there is limited evidence of pro-active ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 9 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 9-10 Total pages: 225 1 climate adaptation in African cities. Proactive adaptation policy could reduce road repair and maintenance 2 costs by 74% compared to a reactive policy. Adapting roads for increased temperatures and investment in 3 public transport are assessed as 'no regret' options. In contrast, hydropower development carries risk of 4 regrets due to damages when a different climate than was expected materializes. Energy costs for cooling 5 demands are projected to accumulate to USD 51.3 billion in 2035 at 2℃ global warming and to USD 486.5 6 billion in 2076 at 4℃. {9.8.5} 7 8 Reduced drought and flood risk, and improved water and sanitation access, can be delivered by: 9 water-sensitive and climate scenario planning, monitored groundwater use, waterless on-site 10 sanitation, rainwater harvesting and water reuse, reducing risk to human settlements, food systems, 11 economies, and human health (high confidence). {9.8, 9.9, 9.10, 9.11} 12 13 Water sector adaptation measures show medium social and economic feasibility but low feasibility for 14 most African cities due to technical and institutional restrictions, particularly for large supply dams 15 and centralised distribution systems (medium confidence). {9.3.1, 9.7.3} Use of integrated water 16 management, water supply augmentation, and establishment of decentralised water management systems can 17 reduce risk. Integrated water management measures including sub-national financing, demand management 18 through subsidies, rates and taxes, and sustainable water technologies can reduce water insecurity caused by 19 either drought or floods (medium confidence). {9.7.3; Box 9.4} 20 21 Agricultural and livelihood diversification, agroecological and conservation agriculture practices, 22 aquaculture, on-farm engineering, and agroforestry can increase resilience and sustainability of food 23 systems in Africa under climate change (medium confidence). However, smallholder farmers tend to 24 address short-term shocks or stresses by deploying coping responses rather than transformative adaptations. | 1639 - 164 | Prot-Adapt-Mitig-Impac | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 19 20 21 Table 9.1: Loss and damage from climate change across sectors covered in this report. Loss and damage arise from 22 adverse climate-related impacts and risks from both sudden-onset events, such as floods and cyclones, and slower-onset 23 processes, including droughts, sea level rise, glacial retreat and desertification and includes both include both economic 24 (e.g., loss of assets and crops) and non-economic types (e.g., loss of biodiversity, heritage and health) (UNFCCC Paris 25 Agreement, 2015; IPCC, 2018a; Mechler et al., 2020). Section marked with * and in bold highlights Loss and Damage 26 attributed to anthropogenic climate change (16.1.3). | 1647 - 164 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 10 11 Several key risks were identified for both ecosystems and people including species extinction and ecosystem 12 disruption, loss of food production, reduced economic output and increased poverty, increased disease and 13 loss of human life, increased water and energy insecurity, loss of natural and cultural heritage, and 14 compound extreme events harming human settlements and critical infrastructure (Table 9.2). In order to 15 provide a sector and continent-level perspective, the key risks aggregate across different regions and 16 combine multiple risks within sectors. For detailed assessments of observed impacts and future risks within 17 each sector and each sub-region of Africa, see the sector-specific sections of this chapter (Sections 9.6.1 and 18 9.12.1). | 1648 - 164 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 33 34 Glacial ice cover is projected to disappear before 2030 on the Rwenzori Mountains (Taylor et al., 2006) and 35 Mount Kenya (Prinz et al., 2018) and by 2040 on Kilimanjaro (Cullen et al., 2013). The loss of glaciers is 36 expected to result in a loss in tourism revenues, especially in mountain tourism (Wang and Zhou, 2019). | 1687 - 168 | Impact | | |

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| IPCC_AR6_WGII_Full_Report | (Fabiyi and Oloukoi, 2013; Hooli, 2016; Lunga and Musarurwa, 2016; Bwambale et al., 2018; Tume et al., 2019) Wildfires Early burning to prevent the intensity of the late-season fires Smallholders in Mutoko, Zimbabwe; Khwe and Mbukushu communities in Namibia (Mugambiwa, 2018; Humphrey et al., 2021) Rainfall variability Change crop type (from maize to traditional millet and sorghum); no weeding; forecasting, rainwater harvesting; women perform rituals rainmaking, seed dressing and crop maintenance as adaptation measures; mulching Communities in Accra, Ghana; small-scale farmers in Ngamiland in Botswana; Malawi; Zimbabwe; Women in Dikgale, South Africa, agropastoral smallholders in Ntungamo, Kamuli and Sembabule in Uganda. | 1689 - 168 | Prot-Adapt-Mitig- | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 15 16 Mangroves, seagrasses and coral reefs support nursery habitats for fish, sequester carbon, trap sediment and 17 provide shoreline protection (Ghermandi et al., 2019). Climate change is compromising these ecosystem 18 services (medium confidence). Marine heatwaves associated with El Niño-Southern Oscillation (ENSO) 19 events triggered massive coral bleaching and mortality over the past 20 years (Oliver et al., 2018). Mass 20 coral bleaching in the western Indian Ocean occurred in 1998, 2005, 2010 and 2015/2016 with coral cover 21 just 30–40% of 1998 levels by 2016 (Obura et al., 2017; Moustahfid et al., 2018). The northern Mozambique 22 Channel has served as a refuge from climate change and biological reservoir for the entire coastal East 23 African region (McClanahan et al., 2014; Hoegh-Guldberg et al., 2018). A southern shift of mangrove 24 species has been observed in South Africa (Peer et al., 2018) with loss in total suitable coastal habitats for 25 mangroves and shifts in the distribution of some species of mangroves and a gain for others (Record et al., 26 2013). Mangrove cover was reduced 48% in Mozambique in 2000 from tropical cyclone Eline, with 100% 27 mortality of seaward mangroves dominated by Rhizophora mucronata (Macamo et al., 2016). Recovery of 28 mangrove species was observed 14 years later in sheltered sites. There is low confidence these cyclone- 29 induced impacts are attributable to climate change owing, in part, to a lack of reliable long-term data sets 30 (Macamo et al., 2016). In West Africa, oil and gas extraction, deforestation, canalisation and de-silting of 31 waterways have been the largest factors in mangrove destruction (Numbere, 2019). | 1694 - 169 | 'rot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGII_Full_Report | 14 15 16 9.6.2.2 Terrestrial Biodiversity 17 18 Local extinction is when a species is extirpated from a local site. The magnitude and extent of local 19 extinctions predicted across Africa increase substantially under all future global warming levels (high 20 confidence) (Table 9.5; Figure 9.19). Above 2℃ the risk of sudden disruption or loss of local biodiversity, 21 increases and becomes more widespread, especially in Central, West and East Africa (Trisos et al., 2020). | 1695 - 169 | Impact | | |
| IPCC_AR6_WGII_Full_Report | Global Warming Level (relative to 1850-1900) Taxa % of species at a site at risk of local extinction Extent across Africa (% of the land area of Africa) Areas at risk References 1.5℃ Plants, insects, vertebrates >10% >90% Widespread. Hot and/or arid regions especially at risk, including Sahara, Sahel and Kalahari Fig. 9.29b (Newbold, 2018; Warren et al., 2018) >2℃ Plants, insects, vertebrates >50% 18% Widespread (Newbold, 2018; Warren et al., 2018) >4℃ Plants, insects, vertebrates >50% 45-73% Widespread. Higher uncertainty for central African tropical forests due to lower agreement between biodiversity models Fig. 9.29c (Barbet-Massin and Jetz, 2015; Newbold, 2018; Warren et al., 2018) 12 13 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 9 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 9-67 Total pages: 225 1 2 Figure 9.19: The loss of African biodiversity under future climate change is projected to be widespread and increasing 3 substantially with every 0.5℃ above the current (2001–2020) level of global warming (high confidence). (a) Projected 4 biodiversity loss, quantified as percentage change in species abundance, range size or area of suitable habitat increases 5 with increasing global warming levels (relative to 1850–1900). Above 1.5℃ global warming, half of all assessed 6 species are projected to lose >30% of their population, range size or area of suitable habitat, with losses increasing to 7 >40% for >3℃. The 2001–2020 level of global warming is around 1℃ higher than 1850–1900 (IPCC, 2021). Boxplots 8 show the median (horizontal line), 50% quantiles (box), and points are studies of individual species or of multiple 9 species (symbol size indicates the number of species in a study). (b–c) The mean projected local extinction of 10 vertebrates, plants and insects within 100 km grid cells increases in severity and extent under increased global warming 11 (relative to 1850–1900). Local extinction >10% is widespread by 1.5℃. Pixel colour shows the projected percentage of 12 species undergoing local extinction and the agreement between multiple biodiversity models. (d–e) The mean projected 13 increase in species of freshwater fish vulnerable to local extinction within 10 km grid cells for future global warming. | 1696 - 169 | Impact<br>Impact | | |
| IPCC_AR6_WGII_Full_Report | 19 20 9.6.3 Nature-Based Tourism in Africa 21 22 Nature-based tourism is important for African economies and jobs. Tourism contributed 8.5% of Africa's 23 2018 GDP (World Travel and Tourism Council, 2019a) with Wildlife tourism contributing a third of tourism 24 revenue (USD 70.6 billion), supporting 8.8 million jobs (World Travel and Tourism Council, 2019b). | 1699 - 1699 | | | |

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| IPCC_AR6_WGII_Full_Report | 25 26 Climate change is already negatively affecting tourism in Africa (high confidence). The 2015–2018 Cape 27 Town drought caused severe water restrictions, reducing tourist arrivals and spending with associated job 28 losses (Dube et al., 2020). Anthropogenic climate change increased the likelihood of drought by a factor of 29 five to six (Pascale et al., 2020). Extreme heat days have increased across South African national parks since 30 the 1990s (van Wilgen et al., 2016). This reduces animal mobility, decreasing animal viewing opportunities 31 (Dube and Nhamo, 2020). Tourists and employees also fear heat stress (Dube and Nhamo, 2020). Visitors to 32 South Africa's national parks preferred to visit in cool-to-mild temperatures (Coldrey and Turpie, 2020). | 1699 - 1699 | | | |
| IPCC_AR6_WGII_Full_Report | 33 Extreme weather conditions disrupted tourist activities and damaged infrastructure at Victoria Falls, Hwange 34 National Park, Kruger National Park and the Okavango Delta (Dube et al., 2018; Dube and Nhamo, 2018; 35 Mushawemhuka et al., 2018; Dube and Nhamo, 2020). Rainfall variability and drought alters wildlife 36 migrations, affecting tourist visits to the Serengeti (Kilungu et al., 2017). Reduced tourism decreases revenue 37 for national park management (van Wilgen et al., 2016). | 1699 - 169 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 38 39 Future climate change is projected to further negatively affect nature-based tourism. Decreased snow and 40 forest cover may reduce visits to Kilimanjaro National Park (Kilungu et al., 2019). Woody plant expansion 41 in savanna and grasslands reduce tourist's game viewing experience and negatively impact conservation 42 revenues (Gray Emma and Bond William, 2013; Arbieu et al., 2017). Visitation rates to South African 43 national parks, based on mean monthly temperatures, are projected to decline 4% with 2℃ global warming 44 (Coldrey and Turpie, 2020). Sea level rise and increased intensity of storms is projected to reduce beach 45 tourism due to beach erosion (Grant, 2015; Amusan and Olutola, 2017). Tourism in the Victoria Falls, 46 Okavango and Chobe hydrological systems may be negatively affected by heat and increased variability of 47 rainfall and river flow (Saarinen et al., 2012; Dube and Nhamo, 2019). Increased extreme heat will increase 48 air turbulence and weight restrictions on aircraft, which could make air travel more uncomfortable and 49 expensive to African destinations (Coffel and Horton, 2015; Dube and Nhamo, 2019). | 1699 - 169 | ʼrot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | 50 51 9.6.3.1 Protected Areas and Climate Change 52 53 African protected areas store around 1.5% of global land ecosystem carbon stocks and support biodiversity 54 (Gray et al., 2016; Melillo et al., 2016; Sala et al., 2018). They also support livelihoods and economies, such 55 as through nature-based tourism and improved fisheries (Brockington and Wilkie, 2015; Mavah et al., 2018; 56 Ban et al., 2019). | 1699 - 169 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | 35 36 Yet many areas targeted by AFR100 erroneously mark Africa's open ecosystems (grasslands, savannas, 37 shrublands) as degraded and suitable for afforestation (Figure Box 9.3.1) (Veldman et al., 2015; Bond et al., 38 2019) (high confidence). These ecosystems are not degraded, they are ancient ecosystems that evolved in the 39 presence of disturbances (fire/herbivory) (Maurin et al., 2014; Bond and Zaloumis, 2016; Charles- 40 Dominique et al., 2016). Afforestation prioritises carbon sequestration at the cost of biodiversity and other 41 ecosystem services (Veldman et al., 2015; Bond et al., 2019). Furthermore, it remains uncertain how much 42 carbon can be sequestered as, compared to grassy ecosystems, afforestation can reduce belowground carbon 43 stores and increase aboveground carbon loss to fire and drought (Yang et al., 2019; Wigley et al., 2020b; 44 Nuñez et al., 2021). Thus, afforested areas may store less carbon than ecosystems they replace (Dass et al., 45 2018; Heilmayr et al., 2020). Afforestation would reduce livestock forage, eco-tourism potential and water 46 availability (Gray Emma and Bond William, 2013; Anadón et al., 2014; Cao et al., 2016; Stafford et al., 47 2017; Du et al., 2021), and may reduce albedo thereby increasing warming (Baldocchi and Penuelas, 2019; 48 Bright et al., 2015). | 1702 - 1702 | | | |

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| IPCC_AR6_WGII_Full_Report | 41 42 A substantial media campaign was launched to inform residents about the severity of the drought and urge 43 water conservation (Booysen et al., 2019; Hellberg, 2019; Ouweneel et al., 2020). Together with stringent 44 demand management through higher water tariffs, this communication campaign played an important role in 45 reducing consumption from 540 to 280 litres per household per day (Booysen et al., 2019; Simpson et al., 46 2019a). Revenue from water sales contributes 14% of Cape Town's total revenue, making it the third-largest 47 source of 'own' revenue for the city (Simpson et al., 2019b). However, with an unprecedented reduction in 48 water use, the municipal budget was undermined (Simpson et al., 2020b). Collecting less revenue created a 49 financial shock as the city struggled to recover operating finance, even while new capital requirements were 50 needed for the development of expensive new water supply projects (Simpson et al., 2019b). This financial 51 shock was compounded by the economic stress of poor agricultural and tourism performance brought about 52 by the drought (Shepherd, 2019; Simpson et al., 2021b). As wealthy residents invested in private, off-grid 53 water supplies, the risk of reduced municipal revenue collections from newly off-grid households aggregated 54 with the risk of reduced tourism, increasing the risk to the reputation of the incumbent administration 55 (Simpson et al., 2021b). This demonstrates how a population cohort with a high response capability to water 56 scarcity can reduce risk while simultaneously increasing risks to the municipality and its capacity to provide 57 water to vulnerable residents (Simpson et al., 2020b). Given that city populations in Africa pay 5–7 times ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 9 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 9-76 Total pages: 225 1 more for water than the average price paid in the United States or Europe (Adamu and Ndi, 2017; Lwasa et 2 al., 2018), municipal finance needs to delink operating revenue from potential climate shocks (see Box 8.6 in 3 Chapter 8). | 1705 - 170 | 'rot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | 45 46 In southern Africa, reductions in rainfall over the Limpopo and Zambezi river basins under 1.5℃ and 2℃ 47 global warming could have adverse impacts on hydropower generation, irrigation, tourism, agriculture and 48 ecosystems (Figure Box 9.5.1) (Maúre et al., 2018), although model projections of strong early summer 49 drying trends remain uncertain (Munday and Washington, 2019). | 1707 - 170 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 11 These studies often represent changes at specific sites in a country or assess changes in the yield and/or 12 suitability for cultivating a specific crop across a larger geographic area. Climate change is projected to have 13 overall positive impacts on sugarcane and Bambara nuts in southern Africa, oil palm in Nigeria and chickpea 14 in Ethiopia (low confidence) (Figure 9.23). | 1717 - 171 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 26 27 For all other crops, there is at least one study that finds low to highly negative impacts for one or several 28 warming levels (Figure 9.23). Mixed results on the direction of change often occur when several contrasting 29 sites with varying baseline climates are studied, and when a study considers the full range of climate 30 scenarios. For example, there are mixed results on the direction of change for impacts of 1.5℃ global 31 warming on cassava, cotton, cocoa and millet in West Africa (low confidence) (Figure 9.23). In general, 32 there is limited evidence in the direction of change, due to single studies being available for most crop- 33 country combinations (Knox et al., 2010; Chemura et al., 2013; Asaminew et al., 2017; Bouregaa, 2019). | 1717 - 171 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 26 27 Although warming temperatures are largely responsible for increasing environmental suitability for mosquito 28 vectors (Mordecai et al., 2019), droughts can augment transmission when open water storage provides 29 breeding sites near human settlements, and when flooding enables mosquitoes to proliferate and spread 30 viruses further (Mweya et al., 2017; Bashir and Hassan, 2019). Within Africa's rapidly growing cities, 31 diseases vectored by urban-adapted Aedes mosquitoes pose a major threat, especially in West Africa 32 (Zahouli et al., 2017; Weetman et al., 2018; Messina et al., 2019). Dengue virus expansion may cause 33 explosive outbreaks but the burden of dengue haemorrhagic fever and associated mortality is higher in areas 34 where transmission is already endemic (Murray et al., 2013). | 1745 - 174 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | 10 Adaptation options can build on a long tradition of community-based services in Africa (Ebi and Otmani Del 11 Barrio, 2017). Indeed, strengthening many of the services already provided (e.g., childhood vaccinations and 12 vector control) will help curtail emerging burdens of climate-sensitive conditions. However, a 13 disproportionate focus on emerging zoonotic and vector-borne viruses could undermine climate change 14 adaptation efforts in Africa if it shifts the focus away from health system strengthening and leaves few 15 resources for addressing other health impacts of climate change. | 1755 - 175 | 'rot-Adapt-Mitig-Impa | INTANBILE | |

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| IPCC_AR6_WGII_Full_Report | 19 20 Improved water, sanitation and hygiene (WASH) requires robust water and sanitation infrastructure 21 (Duncker, 2017; Kohlitz et al., 2017; Venema and Temmer, 2017) and technological adaptations (Gabert, 22 2016; van Wyk et al., 2017), such as waterless on-site sanitation (Sutherland et al., 2021), diversification of 23 water sources (e.g., rainwater harvesting (Lasage and Verburg, 2015) and groundwater abstraction 24 (MacDonald et al., 2012)), and sharing of best practices across the continent (WASH Alliance International, 25 2015; Jack et al., 2016) (see also Section 9.7.3; Chapter 4, Section 4.6.4). Hand hygiene can be improved 26 through the creation of handwashing stations, increased access to soap and simple technologies such as the 27 foot-operated Tippy taps (Coultas and Iyer, 2020; Mbakaya et al., 2020). | 1757 - 175 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | 32 Health promotion initiatives include promoting adequate hydration and simple cooling measures such as 33 drinking cold liquids, water sprays and raising awareness of the symptoms and importance of heat stress, 34 including heatstroke (Aljawabra and Nikolopoulou, 2018). Adaptive measures are especially important for 35 high-risk groups such as outdoor workers, the elderly, pregnant women and infants. Health systems 36 interventions may include early warning systems, heat health regulation, and health workers providing 37 cooling interventions, such as supplying cool water or fans, during heat waves. Changes to the built 38 environment include painting the roofs of houses white and improving ventilation during extreme heat 39 (Codjoe et al., 2020), the use of insulation materials or altering the building materials used for the 40 construction of housing to improve their ability to moderate indoor temperatures (Mathews et al., 1995; 41 Makaka and Meyer, 2006). | 1757 - 175 | 'rot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGII_Full_Report | Response category Co-benefits Inter-sectoral trade�offs and/or drawbacks Enablers Barriers Policy development Policies and plans that facilitate service delivery and guide national and international funding; decreased number of work hours lost; improved work performance, increased productivity Willingness of policymakers; political support; politically willing environment; inter-sectoral collaboration Lack of implementation; poor governance Education & awareness Promotion of sustainable living and circular economy Guarantee to sustained funding; political support; politically willing environment; increased accessibility of learning institutions Lack of implementation; historical and colonisation-related insensitivities Health systems & primary healthcare services Capacity building in communities; buffered economic impact of outbreaks/ disasters; job creation Increased GHG from building; increased energy demand; decreased productivity and increased work hours lost due to waiting times Guarantee to sustained funding; political support; politically willing environment Corruption and fraudulent activities around resource allocation Surveillance, risk assessments, monitoring, & research Evidence to improve adaptation response; fast post-disaster recovery; increased awareness and disease prevention; improved health system functioning post-disasters Requires effective institutional arrangements and inter�sectoral collaboration; guarantee to sustained funding; requires skills development May be limited by uncertainty in modelled predictions and thresholds Resource management Improved health system functioning post-disasters; capacity building in communities; promotes economic growth/stability; increases the tourism potential of the area; increased accessibility/ mobility of the community; reduced land degradation, desertification, and bush encroachment; food security; decreased emissions Increased GHG from building; increased energy demand; increased crowding/ population density; land use; microclimate and ecosystem disruption Guarantee to sustained funding; political support; politically willing environment; requires effective institutional arrangements and inter�sectoral collaboration; requires skills development Corruption and fraudulent activities around resource allocation Vector control & disease prevention Decreased mortality; improved work performance; increased productivity; improved mental health Increased GHG; decreased biodiversity; environmental impacts of production, packaging, and delivery; potentially detrimental to health Guarantee to sustained funding; funding and resources; future planning or retrofit required Last-mile access; cost per capita and capacity for service delivery 5 6 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 9 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 9-130 Total pages: 225 1 9.11 Economy, Poverty and Livelihoods 2 3 9.11.1 Observed Impacts of Climate Change on African Economies and Livelihoods 4 5 9.11.1.1 Economic Output and Growth 6 7 Increased average temperatures and lower rainfall have reduced economic output and growth in Africa, with 8 larger negative impacts than other regions of the world (Abidoye and Odusola, 2015; Burke et al., 2015a; 9 Acevedo et al., 2017; Kalkuhl and Wenz, 2020). In one estimate, GDP per capita is on average 13.6% lower 10 for African countries than it would be if anthropogenic warming since 1991 had not occurred (Diffenbaugh 11 and Burke, 2019), although impacts vary substantially across countries (see Figure 9.37). As such, global 12 warming has increased economic inequality between temperate, Northern Hemisphere countries and those in 13 Africa (Diffenbaugh and Burke, 2019). | 1759 - 176 | 'rot-Adapt-Mitig-Impac | | |

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| IPCC_AR6_WGII_Full_Report | 20 21 Aggregate macroeconomic impacts manifest through many channels (Carleton et al., 2016). Macroeconomic 22 evidence suggests aggregate impacts occurred largely through losses in agriculture with a smaller role for 23 manufacturing (Barrios et al., 2010; Burke et al., 2015b; Acevedo et al., 2017). Sector-specific analyses 24 confirm that declines in productivity of food crops, commodity crops and overall land productivity 25 contribute to lower macroeconomic performance under rising temperatures (Schlenker and Lobell, 2010; 26 Bezabih et al., 2011; Jaramillo et al., 2011; Lobell et al., 2011; Adhikari et al., 2015). Labour supply and 27 productivity declines in manufacturing, industry, services and daily wage labour have been observed in other 28 regions (Graff Zivin and Neidell, 2014; Somanathan et al., 2015; Day et al., 2019; Nath, 2020) and 29 contribute to aggregate economic declines, countering aggregate poverty reduction strategies and other 30 sustainable development goals (Satterthwaite and Bartlett, 2017; Day et al., 2019). In a case study of a rural 31 town in South Africa, over 80% of businesses (both formal and informal) lost over 50% of employees and 32 revenue due to agricultural drought (Hlalele et al., 2016). Drought and extreme heat events have also reduced 33 tourism revenues in Africa (Section 9.6.3). Infrastructure damage and transport disruptions from adverse 34 climate events reduce access to services and growth opportunities (Chinowsky et al., 2014). In global 35 datasets including Africa, tropical cyclones have been shown to have large and long-lasting negative impacts 36 on GDP growth (Hsiang and Jina, 2014). | 1760 - 176 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 5 While these reallocation effects may be large, current evidence is mixed regarding whether such adjustment 6 of production will dampen or amplify overall social costs of climate change in Africa (Costinot et al., 2012; 7 Bren d'Amour et al., 2016; Wenz and Levermann, 2016; Nath, 2020), as food prices are projected to rise by 8 2080-2099 across all African countries under a scenario with high challenges to mitigation and adaptation 9 (SSP3 and RCP8.5), with the largest price effects (up to 120%) experienced in Niger, Chad and Sudan (Nath, 10 2020). Moreover, reallocating production of agriculture abroad could be maladaptive if it leads to decline or 11 replacement of traditional sectors by industrial and service sectors which could lead to land abandonment, 12 food insecurity and loss of traditional practices and cultural heritage (Thorn et al., 2020; Gebre and Rahut, 13 2021; Nyiwul, 2021). | 1764 - 176 | 'rot-Adapt-Mitig-Impact | | |
| IPCC_AR6_WGII_Full_Report | 29 30 [END BOX 9.9 HERE] 31 32 33 9.12 Heritage 34 35 Africa is a rich reservoir of heritage resources and indigenous knowledge, showcased by about 96 sites 36 inscribed by UNESCO as World Heritage Sites (UNESCO, 2018b). These include 53 sites specifically 37 denoted as having great cultural importance and 5 sites with mixed heritage values. Unfortunately, valuable 38 cultural heritage in forms of tangible evidence of past human endeavour, and the intangible heritage 39 encapsulated by diverse cultural practices of many communities (Feary et al., 2016), is under great threat 40 from climate change. | 1772 - 1772 | | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 43 44 For more than 10,000 years, Africans recorded over 8,000 painted and engraved images on rock shelters and 45 rock outcroppings across 800 exceptional rock art sites of incalculable value (Hall et al., 2007; di Lernia and 46 Gallinaro, 2011; di Lernia, 2017; Clarke and Brooks, 2018; Barnett, 2019), but which are exceptionally 47 fragile to the elements. Unfortunately, there has been a poor study of direct climate change impacts on rock 48 art across Africa. | 1772 - 177 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 49 50 Underwater heritage includes shipwrecks and artefacts lost at sea and extends to prehistoric sites, sunken 51 towns and ancient ports that are now submerged due to climatic or geological changes (Spalding, 2011). Off 52 the shores of Africa, about 111 shipwrecks have been documented, with South Africa having a major share 53 of about 41 sites. The sunken Egyptian city of Thonis-Heracleion and its associated 60+ shipwrecks reflect 54 the richness of Africa's waters. Unfortunately, increased storm surges and violent weather currently threaten 55 the integrity of shipwrecks by accelerating the destruction of wooden parts and other features (Harkin et al., 56 2020). However, climate change impacts on underwater cultural heritage sites are poorly studied, as it ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 9 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 9-143 Total pages: 225 1 requires specialist assessment techniques (Feary et al., 2016), and marine archaeology studies are not well- 2 established in Africa. | 1772 - 177 | Impact | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 3 4 Intangible heritage includes instruments, objects, artefacts and cultural spaces associated with communities, 5 and are almost always held orally (UNESCO, 2003). Loss of heritage assets may be a direct consequence of 6 climate change/variability (Markham et al., 2016), or a consequence of indirect factors resulting from 7 climate change, for example, economic instability and poor decision-making in areas of governance. In 8 northern Nigeria, climate change exacerbates the impact of poor land use decisions, reducing the flow of the 9 Yobe River and negatively impacting the Bade fishing festival because the available fish species continue to 10 decline (Oruonye, 2010). Similarly, Lake Sanké in Mali has been degraded by a combination of urban 11 development and poor rainfall, threatening the Sanké mon collective fishing rite (UNESCO, 2018b). | 1773 - 177 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 17 18 Case study: Traditional earthen 'green energy' buildings 19 Historically, Africa has had a unique and sustainable architecture (Diop, 2018) characterised by area- 20 specific, traditional earthen materials and associated indigenous technology. Key examples include Tiébélé 21 in Burkina Faso, Walata in Mauritania, Akan in Ghana, Ghadames in Libya, Old Towns of Djenné in Mali 22 (World Heritage Site) and other diverse earthen architecture across sub-Saharan Africa. Adegun and Adedeji 23 (2017) indicate that earthen materials provide advantages in thermal conductivity, resistivity and diffusivity, 24 indoor and outdoor temperature, as well as cooling and heating capacities. Moreover, earthen materials are 25 recyclable and environmentally 'cleaner' (Sanya, 2012) because of the absence or small quantity of cement 26 in production, thus reducing carbon emissions. Despite these advantages, the expertise and socio-cultural 27 ceremonies that accompany building and renewal of earthen architecture are disappearing fast (Adegun and 28 Adedeji, 2017). Further, earthen construction is being threatened by extreme climatic variability and 29 changing climate that exacerbates decay (Brimblecombe et al., 2011; Bosman and Van der Westhuizen, 30 2014; Brooks et al., 2020). | 1773 - 177 | Impact | | INDG |
| IPCC_AR6_WGII_Full_Report | 31 32 9.12.2 Projected Risks 33 34 Sea level rise and its associated hazards will present increasing climate risk to African heritage in the coming 35 decades (Marzeion and Levermann, 2014; Reimann et al., 2018; Brito and Naia, 2020) (Figure 9.38). | 1773 - 177 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 36 Although no continental assessment has quantified climate risk to African heritage and little is known of near 37 term exposure to hazards such as sea level rise and erosion, for a handful of coastal heritage sites included in 38 global or Mediterranean studies, 10 cultural sites are identified to be physically exposed to sea level rise by 39 2100 at high emissions scenarios (RCP8.5) (Marzeion and Levermann, 2014; Reimann et al., 2018), of 40 which, 7 World Heritage Sites in the Mediterranean are also projected to face medium or high risk of erosion 41 (Reimann et al., 2018) (Figure 9.38). Further, Brito and Naia (2020) identify natural heritage sites across 27 42 African countries that will be affected by sea level rise by 2100 (RCP8.5), of which 15 sites covering eight 43 countries demonstrated a high need for proactive management actions because of high levels of biodiversity, 44 international conservation relevance and exposure to sea level rise (Figure 9.38). These nascent studies 45 highlight the potential severity of risk and loss and damage from climate change to African heritage, as well 46 as gaps in knowledge of climate risk to African cultural and natural, particularly concerning bio-cultural 47 heritage. | 1773 - 177 | 'rot-Adapt-Mitig-Impact | | |
| IPCC_AR6_WGII_Full_Report | 48 49 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 9 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 9-144 Total pages: 225 1 2 Figure 9.38: Risk to Africa's cultural and natural coastal heritage sites from sea level rise and erosion by 2100 3 (RCP8.5). Panel (a) Exposed World Heritage sites projected to be affected by sea level rise under a high-end sea level 4 rise scenario (RCP8.5, 2100) (Marzeion and Levermann, 2014; Reimann et al., 2018). Panel a call out) Sites identified 5 to be also exposed to medium and high erosion risk under current and future conditions (2000 and 2100) under a high- 6 end sea level rise scenario (Reimann et al., 2018). Panel (b) The 15 topmost African natural sites (coastal protected 7 areas) identified to be exposed to negative impacts from sea level rise and as priority for conservation (Brito and Naia, 8 2020). | 1773 - 177 | 'rot-Adapt-Mitig-Impact | | |
| IPCC_AR6_WGII_Full_Report | 9 10 11 Although climate change is a significant risk to heritage sites (Brito and Naia, 2020), there is little research 12 on how heritage management is adapting to climate change, and particularly, whether the capacity of current 13 heritage management systems can prepare for and deal with consequences of climate change (Phillips, 2015) 14 (see also Cross-Chapter Box SLR in Chapter 3). | 1774 - 177 | 'rot-Adapt-Mitig-Impac | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 15 16 Worsening climate impacts are cumulative and often exacerbate the vulnerability of cultural heritage sites to 17 other existing risks, including conflict, terrorism, poverty, invasive species, competition for natural resources 18 and pollution (Markham et al., 2016). These issues may affect a broad range of tourism segments, including 19 beach vacation sites, safari tourism, cultural tourism and visits to historic cities (UNWTO, 2008). Climate 20 change impacts have the potential to increase tourist safety concerns, especially at sites where increased 21 intensity of extreme weather events or vulnerability to floods and landslides are projected (Markham et al., 22 2016) (see also Cross-Chapter Box EXTREMES in Chapter 2). There may also be circumstances where 23 interventions required to preserve and protect the resource alter its cultural significance (van Wyk, 2017). | 1774 - 177 | 'rot-Adapt-Mitig-Impact | | |
| IPCC_AR6_WGII_Full_Report | 24 25 9.12.3 Adaptation 26 27 Research highlights potential in integrating indigenous knowledge, land use practices, scientific knowledge 28 and heritage values to co-produce tools that refine our understanding of climate change and variability and 29 develop comprehensive heritage adaptation policy (Ekblom et al., 2019) (Table 9.13). | 1774 - 177 | Prot-Adapt-Mitig- | | INDG |
| IPCC_AR6_WGII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 9 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 9-145 Total pages: 225 1 Table 9.13: Examples of responses to climate change impacts to heritage sites. | 1774 - 177 | Impact | | |
| IPCC_AR6_WGII_Full_Report | Heritage Type Example Type of Climate Impact Intervention Focus or Activity Main Intervention Activity State of Materials Final State of Heritage Literature Tangible Ancient Historic buildings Ounga Byzantine Fort and associated archaeological remains, Tunisia Coastal erosion Archaeological conservation of fort Building repairs to outer walls of fort but other archaeological areas no intervention Mixed. Fort is in good condition, but other parts of the site are under threat of coastal erosion, particularly lesser archaeological remains of other periods Some aspects of site well preserved, other parts damaged (Slim et al., 2004) Archaeolo gical sites Sabratha, Roman City, Libyan coast Sea level rise, local flooding and coastal erosion Monitoring of condition None Loss of archaeological remains into the sea Some aspects of site well preserved, other parts damaged (Abdalahh, 2011) Living Cities / towns Lamu Old Town and archipelago, Kenya Sea Level Rise impacting low lying areas and climate variability impacting protective mangroves Lamu Old Town managed by National Museums of Kenya the mangrove forests by Community Forest Associations and Forest Conservation and Management Act of 2016. Changes in biodiversity and cultural resilience to climate shocks. | 1775 - 177 | 'rot-Adapt-Mitig-Impact | | |

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| IPCC_AR6_WGII_Full_Report | Current and ongoing conservation Stable (Birabi and Nawangwe, 2011) Bio�cultural Rock art Golden Gate Highlands, South Africa Precipitation and atmospheric changes Monitoring of condition No known intervention Biodeterioration of condition of rock surface Increasing loss of rock surfaces (Viles and Cutler, 2012) ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 9 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 9-146 Total pages: 225 causing luxuriant lichen growth and images on the rock surfaces Intangible (indigenou s) Language !Xun and Khwe Indigenous Youth of South Africa Climate variability causing drought and loss of plants Groups (youth) Documentation Non-formal, local Enhancem ent, promotion (Bodunrin, 2019) Indigenous Language Use in Agricultural Radio Programming in Nigeria Climate variability increasing frequency of drought Farmer groups, communities Research, documentation Formal, local Promotion, transmissio n (Adeyeye et al., 2020) Rituals Enkipaata, Eunoto and Olng'esherr Maasai male rites of passage Climate variability causing drought Maasai community groups Identification, documentation, research Formal, non-formal, local, foreign promotion (UNESCO, 2018a) Customs & beliefs Sanké mon fishing festival in Mali Climate variability reducing rainfall Malinkés, Bambara and Buwa communities Identification, documentation, preservation Formal, non-formal, local promotion (UNESCO, 2009) Indigenou s engineerin g systems Water measurers of the Foggara irrigation system in Algeria Increased siltation and sandstorms Climate variability causing flooding Touat and Tidikelt communities Research, identification, documentation Formal, local transmissio n (Mokadem et al., 2018) Arts and crafts Traditional crafts made from various parts of the Date Palm in Egypt, Mauritania, Morocco, Sudan, Tunisia and other countries outside Africa Climate variability causing shift in plant habitats Residents of oases, groups, communities, agricultural cooperative societies Research, identification, documentation, preservation, protection Formal, non-formal, local, foreign Transmissi on, promotion, enhanceme nt, revitalizati on (UNESCO, 2003) (Shabani et al., 2012) 1 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 9 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 9-147 Total pages: 225 1 Conservation of heritage may require offsetting the impact of loss through partial or total excavation under 2 certain circumstances, like environment instability, or where in situ heritage preservation is exorbitant in cost 3 (Maarleveld and Guérin, 2013). | 1775 - 177 | 'rot-Adapt-Mitig-Impac | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 4 5 Although many underwater shipwrecks and ruins of cities are currently preserved better in situ than similar 6 sites on land (Feary et al., 2016), preserving such heritage is often financially prohibitive with many physical 7 and technical challenges. Further, skill capacities of heritage agencies are limited to a few qualified 8 archaeologists in Africa (Maarleveld and Guérin, 2013). | 1777 - 1777 | | | |
| IPCC_AR6_WGII_Full_Report | 9 10 For centuries, Africans have drawn on intangible heritage to enhance their resilience to climatic variability 11 and support adaptation practices. For example, pastoralist communities have historically translated their 12 experiences into memories that can be 'translated' into diverse adaptive practices (Oba, 2014). In coastal 13 Kenya, Mijikenda communities rely on indigenous knowledge and practices used in the management of the 14 sacred Kaya Forests to adapt their farming to a changing climate (Wekesa et al., 2015). | 1777 - 177 | Prot-Adapt-Mitig- | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 15 16 Hence, preservation measures for transforming oral information into written records should ensure viability 17 of intangible cultural heritage by giving due consideration to the confidentiality of culturally sensitive 18 information and intellectual property rights (Feary et al., 2016). | 1777 - 1777 | | | |
| IPCC_AR6_WGII_Full_Report | 19 20 Inclusion of cultural landscapes and intangible heritage in the landscape approach at the regional scale 21 development planning processes may have significant impacts on protected area management (Feary et al., 22 2016). For example, at the Domboshava rock art site in Zimbabwe, all management decisions are taken in 23 direct consultation with traditional leaders and other stakeholders from surrounding communities (Chirikure 24 et al., 2010). Such adaptation strategies promote a more open-minded approach to heritage by leveraging 25 local development (UNESCO, 2018b). | 1777 - 177 | 'rot-Adapt-Mitig-Impac | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 26 27 Lack of expertise and resources, together with legislation that privileges certain typologies of heritage, seem 28 to limit implementation of approved policies (Ndoro, 2015). Additionally, cultural heritage has least priority 29 in terms of budgetary allocation, capacity building and inclusion into school curricula. Failure to consider the 30 views of people who attach spiritual significance to places is detrimental to the conservation of heritage 31 places (Bwasiri, 2011). In particular, documented cases of local people having to pay an entrance fee, like 32 tourists, to access burial grounds and places of pilgrimage negate local participation in cultural site 33 management (Ndoro, 2015). | 1777 - 177 | Prot-Adapt-Mitig- | INTANBILE | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 34 35 In the long term, heritage managers and local authorities could shift from planning primarily for disaster 36 response and recovery to strategies that focus on disaster preparedness, reducing the vulnerability of sites 37 and strengthening resilience of local communities (UNFCCC, 2007; Domke and Pretzsch, 2016). This could 38 evolve into innovative approaches that integrate community, government and the research sector in 39 productive cultural heritage management partnerships. | 1777 - 1777 | | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 40 41 There is a need for institutions to establish, maintain and update a comprehensive inventory of underwater 42 cultural heritage. This can be done using non-intrusive, detailed mapping of the wreck site and a 3D model 43 from which scientists can reconstruct the site in detail (Maarleveld and Guérin, 2013). | 1777 - 1777 | | | |
| IPCC_AR6_WGII_Full_Report | 4 Significant warming has intensified the threat to social and economic sustainability in Asia (medium 5 confidence). Rising temperature increases likelihood of the threat of heat waves across Asia, droughts in arid 6 and semi-arid areas of West, Central and South Asia, delays and weakening of the monsoon circulation in 7 South Asia, floods in monsoon regions in South, Southeast and East Asia, and glacier melting in the Hindu 8 Kush Himalaya (HKH) region (medium confidence). {10.3.1; 10.3.3} 9 10 Asian countries are experiencing a hotter summer climate, resulting in increase of energy demand for 11 cooling at a rapid rate, together with the population growth (high confidence). Decrease in 12 precipitation influences energy demand as well, as desalination, underground water pumping and 13 other energy-intensive methods are increasingly used for water supply (high confidence). More energy 14 demands in summer seasons will exceed any energy savings from relatively lower heating demand due to 15 warmer winter. Among thirteen developing countries with large energy consumption in Asia, eleven are 16 exposed to high energy insecurity and industrial systems risk (high confidence). {10.4.1} 17 18 Asian terrestrial ecosystems change is driven by global warming, precipitation and Asian monsoon 19 alteration, permafrost thawing and extreme events like dust storms along with natural and human- 20 related factors which are in interplay (high confidence). Treeline position in North Asian mountains 21 moves upward after 1990s, while in Himalaya treeline demonstrates a multidirectional shift, either moves 22 upward, or does not show upslope advance or moves downward. This can be explained by site-specific 23 complex interaction of positive effect of warming on tree growth, drought stress, change in snow 24 precipitation, land use change, especially grazing, and other factors (high confidence). The increased 25 considerably changes in biomes in Asia are a response to warming (medium confidence). Terrestrial and 26 freshwater species, populations, and communities alter in line with climate change across Asia (medium-to- 27 high confidence). Climate change, human activity, and lightning determine the increase of wildfire severity 28 and area burned in North Asia after 1990s (medium confidence). Length of plant growth season increased in 29 some parts of East and North Asia, while opposite trend or no change was observed in other parts (high 30 confidence). Observed biodiversity or habitat losses of animals or plants were linked to climate change in 31 some parts of Asia (high confidence). There are evidences that climate change can alter species interaction or 32 spatial distribution of invasive species in Asia (high confidence). Changes in ecosystems in Asia during the 33 21st century are expected to be driven by projected climatic, natural, and socioeconomic changes. Across 34 Asia, under a range of RCPs and other scenarios rising temperature is expected to contribute to northward 35 shift of biome boundaries and upward shift of mountain treeline (medium confidence). {10.4.2} 36 37 Coastal habitats of Asia are diverse and the impacts of climate change including rising temperature, 38 ocean acidification and sea level rise has brought negative effects to the services and the livelihood of 39 people depending on it (high confidence). The degree of bleaching of coral reefs was diverse among 40 different presences of stress tolerant symbionts and higher thermal thresholds. The risk of irreversible loss of 41 coral reefs, tidal marshes, seagrass meadows, plankton community and other marine and coastal ecosystems 42 increases with global warming, especially at 2°C temperature rise or more (high confidence). Mangroves in 43 the region continue to face threats due to pollution, conversion for aquaculture, agriculture, in addition to 44 climate based threats like SLR (Sea Level Rise) and coastal erosion. | 1858 - 185 | Impact | INTANBILE | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 10 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 10-4 Total pages: 172 1 2 The Asia glaciers are in minor area shrinkage and mass loss during 2006-2016, resulting in the 3 instability of water resource supply (high confidence). Glaciers in Asia are the water resources of about 4 220 million people in the downstream areas. The glacier meltwater in southern Tibetan Plateau has increased during 1998-2007, and will further increase till 2050. The glacier is likely2 5 to disappear by nearly 50% in 6 High Mountain Asia and about 70% in Central and Western Asia by the end of the 21st century under the 7 medium scenario, and more under the high scenario. The total amount and area of glacier lakes were found 8 increased during last decade (high confidence). More glacier collapses and surges were found in western 9 Tibet. Glacier lake outburst flood (GLOF) will threaten the securities of the local and downstream 10 communities (high confidence). Snowmelt water contributed 19% of the increase change in runoff of arid 11 region's rivers in Xinjiang, China and 10.6% of the upper Brahmaputra River during 2003-2014 (medium 12 confidence). {10.4.4; Box 10.5} 13 14 Since IPCC AR5, more studies reinforce the earlier findings on the spatial and temporal diversity of climate 15 change impacts on food production in Asia depending on the geographic location, agro ecology, and crops 16 grown, recognizing that there are winners and losers associated with the changing climate across scales (high 17 confidence). Most of these impacts have been associated with drought, monsoon rain, and oceanic oscillations, the 18 frequency and severity of which have been linked with the changing climate. Climate-related risks to agriculture 19 and food systems in Asia will progressively escalate with the changing climate, with differentiated impacts 20 across the region (medium confidence). Major projected impacts of climate change in the agriculture and 21 food sector include decline in fisheries, aquaculture, and crop production particularly in South and Southeast 22 Asia, reduction in livestock production in Mongolia, and changes in crop, farming systems and crop areas in 23 almost all regions with negative implications to food security (medium confidence). In India, rice production 24 can decrease from 10% to 30% whereas maize production can decrease from 25% to 70% assuming a range 25 of temperature increase from 1º to 4°C. Similarly, rice production in Cambodia can decrease by 45% by 26 2080 under high emission scenario. Occurrence of pests such as the golden apple snail (Pomacea 27 canaliculate), associated with the predicted increase in climatically suitable habitats in 2080, threatens the 28 top Asian rice-producing countries including China, India, Indonesia, Bangladesh, Vietnam, Thailand, 29 Myanmar, Philippines and Japan. Increasing temperatures, changing precipitation levels, and extreme 30 climate events like heat waves, droughts and typhoons will persist to be important vulnerability drivers that 31 will shape agricultural productivity particularly in South Asia, Southeast Asia, and Central Asia. {10.4.5; 32 Figure 10.6} 33 34 Asian urban areas are considered high risk locations from projected climate, extreme events, 35 unplanned urbanisation, rapid land use change (high confidence) but also sites of ongoing adaptation 36 (medium confidence). Asia is home to the largest share of people living in informal settlements, with 332 37 million in Eastern and South-Eastern Asia, 197 million in Central and Southern Asia. By 2050, 64% of 38 Asia's population will be urban. Coastal cities, especially in South and South East Asia are expected to see 39 significant increase in average annual economic losses between 2005 and 2050 due to flooding, with very 40 high | 1858 - 185 | Prot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGII_Full_Report | 22 23 Drawing upon a greater number of studies made possible by greater use of advanced research tools such as 24 remote sensing as well as meticulous modelling of impacts, the Fifth Assessment Report could significantly 25 expand its coverage of pertinent issues (IPCC, 2014c). For example, the discussion on the Himalayas was 26 expanded to cover observed and projected impacts of climate change on tourism (see WGII AR5 Section 27 10.6.2); livelihood assets such as water and food (WGII AR5 Sections 9.3.3.1, 13.3.1.1, 18.5.3, 19.6.3); 28 poverty (WGII AR5 Section 13.3.2.3); culture (WGII AR5 Section 12.3.2); flood risks (WGII AR5 Sections 29 18.3.1.1, 24.2.1); health risks (WGII AR5 Section 24.4.6.2); and ecosystems (WGII AR5 Section 30 24.4.2.2)(IPCC, 2014c). | 1863 - 186 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 38 39 Biodiversity and ecosystem services play a critical role in socioeconomic development as well as the cultural 40 and spiritual fulfilment of the population in the Asia (IPBES, 2018). For example, species richness reaches it 41 maximum in the "coral triangle" of South-East Asia (central Philippines and central Indonesia) (IPCA, 2017) 42 and the extent of mangrove forests in Asia is about 38.7% of the global total (Bunting et al., 2018). These 43 coastal ecosystems provide multiple ecosystem services related to food production by fisheries/aquaculture, 44 carbon sequestration, coastal protection, and tourism/Recreation (Ruckelshaus et al., 2013). | 1868 - 186 | Prot-Adapt-Mitig- | INTANBILE | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 28 29 10.4.2.1 Observed Impacts 30 31 10.4.2.1.1 Biomes and mountain treeline 32 Changes in biomes in Asia are compatible with a response to regional SAT increase (Arias et al., 2021) 33 (medium agreement, medium evidence). Expansion of the boreal forest and reduction of the tundra area is 34 observed for about 60% of latitudinal and altitudinal sites in Siberia (Rees et al., 2020). In Central Siberia, 35 the changes in climate and disturbance regimes are shifting the southern taiga ecotone northward (Brazhnik 36 et al., 2017). In Taimyr, no significant changes in the forest boundary were observed during the last three 37 decades (Pospelova et al., 2017). For the Japanese archipelago, it is suggested that tree community 38 composition change along the temperature gradient is a response to past and/or current climate changes 39 (Suzuki et al., 2015). | 1876 - 187 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 54 In Himalaya, treeline over recent decades either moves upward (Schickhoff et al., 2015; Suwal et al., 2016; 55 Sigdel et al., 2018; Tiwari and Jha, 2018), or does not show upslope advance (Schickhoff et al., 2015; Gaire 56 et al., 2017; Singh et al., 2018c), or moves downward (Bhatta et al., 2018). In Tibetan Plateau, treeline either 57 shifted upwards or showed no significant upward shift (Wang et al., 2019c). This can be explained by site�ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 10 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 10-22 Total pages: 172 1 specific complex interaction of positive effect of warming on tree growth, drought stress, change in snow 2 precipitation, inter- and intraspecific interactions of trees and shrubs, land use change, especially grazing, 3 and other factors (Liang et al., 2014; Lenoir and Svenning, 2015; Tiwari et al., 2017; Sigdel et al., 2018; 4 Tiwari and Jha, 2018; Sigdel et al., 2020). It is largely unknown how broader scale climate inputs, as pre- 5 monsoon droughts interact with local-scale factors to govern treeline response patterns (Schickhoff et al., 6 2015; Müller et al., 2016; Bhatta et al., 2018; Singh et al., 2019b). | 1876 - 187 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 39 40 One of the probable results of global warming is rising high seas level. Scientists believe that increasing 41 greenhouse gases (earth temperature controller) is the reason of this global warming and by using satellite 42 measurements, have forecasted averagely 1-2 mm for rising high seas level (Jafari et al., 2016). The level of 43 thermal stress (based on a degree heating month index, DHMI) at these locations during the 2015–2016 El 44 Niño was unprecedented and stronger than previous ones (Lough et al., 2018) Persian Gulf the reef-bottom 45 temperatures in 2017 were among the hottest on record, with mean daily maxima averaging 35.9 ± 0.10C 46 across sites, with hourly temperatures reaching as high as 37.7o C (Riegl et al., 2018). About 94.3% of corals 47 bleached, and two-thirds of corals suffered mortality in 2017 (Burt et al., 2019). In 2018 coral cover 48 averaged just 7.5% across the southern basin of the Persian Gulf. This mass mortality did not cause dramatic 49 shifts in community composition as earlier bleaching events had removed most sensitive taxa. An exception 50 was the already rare Acropora which were locally extirpated in summer 2017 (Burt et al., 2019). During 51 2008-2011 also the coral communities of Musandam and Oman have shown changes depending on the stress 52 tolerance levels of the species and the local environmental disturbance level (Bento et al., 2016). | 1884 - 1884 | | | |
| IPCC_AR6_WGII_Full_Report | 3 4 An ecosystem-based approach to managing coral reefs in the Gulf of Thailand is needed to identify 5 appropriate marine protected area networks and to strengthen marine and coastal resource policies in order to 6 build coral reef resilience (Sutthacheep et al., 2013). Scope to develop novel mitigation approaches toward 7 coral protection through the use of symbiotic bacteria and their metabolites (Motone et al., 2018); (Motone et 8 al., 2020) has been suggested. Coral culture and transplantation within the Gulf are feasible for helping 9 maintain coral species populations and preserving genomes and adaptive capacities of Gulf corals that are 10 endangered by future thermal stress events (Coles and Riegl, 2013). Greater focus on understanding the 11 flexibility and adaptability of people associated with coral reefs, especially in a time of rapid global change 12 (Hoegh-Guldberg et al., 2019) and a well-designed research program for developing a more targeted policy 13 agenda (Lam et al., 2019). is also recommended. Cutting carbon emissions (Bruno and Valdivia, 2016) and 14 limiting warming to below 1.5˚C is essential to preserving coral reefs worldwide and protecting millions of 15 people (Frieler et al., 2013) (Hoegh-Guldberg et al., 2017). Many visitors to coral reefs have high 16 environmental awareness and reef visitation can both help to fund and to encourage coral reef conservation 17 (Spalding et al., 2017). | 1886 - 188 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | 35 36 Valuation of ecosystem services of mangroves indicated that they prevent more than 1.7 billion US$ in 37 damages for extreme events (1-in-50-year) in Philippines (Menéndez et al., 2018). They reduce flooding to 38 613,500 people/year, 23% of whom live below the poverty line and avert damages to 1 billion US$/year in 39 residential and industrial property. Mangroves have also become very popular as source of livelihood in Asia 40 through tourism (Dehghani et al., 2010),(Kuenzer and Tuan, 2013), (Spalding and Parret, 2019) (Dasgupta et 41 al., 2020. ) and they support fisheries (Hutchison et al., 2014). | 1886 - 188 | Impact | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 7 8 The seagrass meadows are also good sinks of carbon (Fourqurean et al., 2012) capable of storing 9 19.9petagrams (Pg) organic carbon, but with very high regional and site and species variability (Ganguly et 10 al., 2017);(Stankovic et al., 2018); (Gallagher et al., 2019); (Ricart et al., 2020). As highly efficient carbon 11 sinks, these store up to 18 percent of the world's oceanic carbon and they also reduce the impacts of ocean 12 acidification (UNEP, 2020). | 1887 - 188 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 47 48 Seaweeds are important biotic resource capable of capturing carbon and used widely as food, medicine and 49 as raw material for industrial purposes. Warming and altered pH can affect seaweeds indifferent ways (Gao 50 et al., 2016); (Gao et al., 2017); (Gao et al., 2018a), (Wu et al., 2019b). Outbreak of intense blooms of 51 species like Ulva rigida (Gao et al., 2017) and Ulva prolifera (Zhang et al., 2019f) have increased due to 52 varied factors including climate change. These have created huge economic losses in Yellow sea affecting 53 local mariculture, tourism and the functioning of the coastal and marine ecosystems (Zhang et al., 2019f). | 1887 - 1887 | | | |
| IPCC_AR6_WGII_Full_Report | 19 20 Destruction by natural hazards was found to remove the above ground C pool, but the sediment C pool was 21 found to be maintained (Chen et al., 2018b). In Andaman & Nicobar islands the 2004 Indian Ocean Tsunami 22 severely impacted the mangrove habitats at the Nicobar Islands (Nehru and Balasubramanian, 2018),while 23 new inter-tidal habitats suitable for mangrove colonisation developed. Mangrove species with a wide 24 distribution and larger propagules (showed high colonisation potential in the new habitats compared to other 25 species (Nehru and Balasubramanian, 2018) Mangrove sites in Asia are predominantly minerogenic so 26 continued sediment supply is essential for the long-term resilience of Asia's mangroves to SLR (Lovelock et 27 al., 2015; Balke and Friess, 2016; Ward et al., 2016a; Ward et al., 2016b) . | 1888 - 188 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 43 44 10.4.3.4 Adaptation options 45 46 The Nations (2019) has identified establishment of protected areas, restoring ecosystems like mangroves / 47 coral reefs, integrated coastal zone management practices, sand banks and structural technologies and 48 implementing local monitoring networks for increasing adaptive capacity and protecting biodiversity of 49 coastal ecosystem. In Asia, management of marine sites by earmarking protected areas (SDG 14) has been 50 found to be low with only 27% area being protected. In India detailed climate change adaptation guideline 51 coastal protection and management has been prepared considering various environmental and social aspects 52 (Black et al., 2017). The Ocean Health Index for clean waters was also low, 54.6 and the threat to the 53 ecosystem due to combined effect of pollution and climate change was high. Table 10.2 shows the ocean and 54 Marine Protected Areas (MPA). | 1890 - 189 | 'rot-Adapt-Mitig-Impa | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 10 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 10-36 Total pages: 172 1 2 3 Table 10.2: Status of Ocean and MPA. Data Source: (Sachs et al., 2018) Ocean Health Index - Clean waters (0- 100) Fish stocks overexploited or collapsed (%) Ocean Health Index - Fisheries (0-100) Fish caught by trawling (%) Ocean Health Index - Biodiversity (0-100) Marine sites, mean protected area (%) Eastern Asia 54.0 29.1 49.5 39.8 89.6 32.5 South-Eastern Asia 54.1 28.5 54.9 34.7 84.6 25.0 Western Asia 54.3 28.3 46.2 20.4 89.4 18.3 Southern Asia 50.3 17.4 51.0 15.1 88.3 41.2 Northern Asia 91.6 55.4 57.6 60.0 93.4 30.0 Asia 54.6 26.9 50.3 27.3 87.9 27.0 4 5 6 Conservation and Restoration of mangrove were found to be effective tools for enhancing ecosystem carbon 7 storage and an important part of Reducing Emissions from Deforestation and forest Degradation plus 8 (REDD+ ) schemes and climate change mitigation (Ahmed and Glaser, 2016). In East Asia restoration 9 success has been attributed to right geomorphological locations (Van Cuong et al., 2015; Balke and Friess, 10 2016) and co-management models (Johnson and Iizuka, 2016; Veettil et al., 2019). | 1890 - 189 | 'rot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | 11 12 In South Asia, restoration programs have been largely successful (Jayanthi et al., 2018) but in some regions 13 partly a failure due to inappropriate site selection, poor post planting care and other issues (Kodikara et al., 14 2017). Using remote sensing it was observed that there are high recovery rates of mangroves in a relatively 15 short period of time (1.5 years) after a powerful typhoon indicating that natural recovery and regeneration 16 would be a more economically and ecologically viable strategy. Better mangrove management through 17 mapping is suggested (Castillo et al., 2018) (Gandhi and Jones, 2019). Statistical tools developed for 18 modelling biomass and timber volume (Phan et al., 2019) and allometric models to estimate aboveground 19 biomass and carbon stocks (Vinh et al., 2019) will be useful in estimating stocks in mangroves. Future 20 mangrove loss may be offset by increasing national and international conservation initiatives that incorporate 21 mangroves, such as the Sustainable Development Goals, Blue Carbon, and Payments for Ecosystem Services 22 (Friess et al., 2019). Since seagrass meadows and marine macroalage are important habitats capable of 23 combating impacts of climate change, the need for a global networking system with participation of stake 24 holders has been suggested (Duffy et al., 2019). | 1891 - 189 | 'rot-Adapt-Mitig-Impa | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 50 51 The impacts of permafrost changes on regional hydrology in Asia remains unclear. However, those changes 52 may alter the soil carbon storage (e.g. Nie et al., 2019) and increase the riverine carbon exports (e.g. Song et 53 al., 2019). But the fate of soil carbon within permafrost is more complicated and uncertain due to the 54 influences of heterogeneous landforms, as pointed out in China's Second National Soil Survey (Jiang et al., 55 2019). | 1898 - 189 | Impact | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 56 57 [END BOX 10.4 HERE] ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 10 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 10-44 Total pages: 172 1 2 3 10.4.4.5 Climate Vulnerability and Adaptation: Interfaces and Interventions 4 5 In Asia and its diverse sub-regions, the challenge of adaptation to climate change at diverse sectors, sites and 6 scales of vulnerability in the domain of fresh water resources is compounded by the nexus between long- 7 standing non-climatic vulnerabilities and climatic impacts, both observed and projected. Water insecurities in 8 Asia are increasing due to excessive freshwater withdrawals (Satoh et al., 2017) economic and population 9 growth (Gleick and Iceland, 2018), urbanisation and peri urbanisation (Roth et al., 2019) food insecurity 10 (Demin, 2014) and lack of access to clean and safe drinking water (Cullet, 2016) which mostly affects the 11 heath of most vulnerable sections of society. | 1898 - 189 | 'rot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | 17 18 MHW are a new threat to fisheries and aquaculture (Froehlich et al., 2018; Frölicher and Laufkötter, 2018) 19 including disease spread (Oliver et al., 2017), live feed culture (copepods) (Doan et al., 2018), and farming 20 of finfishes like Cobia (Le et al., 2020). Predicting MHW is considered a pre-requisite for increasing the 21 preparedness of farmers (Frölicher and Laufkötter, 2018). In Southeast Asian countries more than 30% of 22 aquaculture areas are predicted to become unsuitable for production by 2050 - 2070 and aquaculture 23 production is predicted to reduce 10% - 20% by 2050 - 2070 due to climate change (Froehlich et al., 2018). | 1903 - 1903 | | | |
| IPCC_AR6_WGII_Full_Report | 25 26 Asian farmers and fisherfolks already employ a variety of adaptation practices to minimise the adverse 27 impacts of climate change. A recent systematic and comprehensive review of farmers' adaptation practices 28 in Asia, Shaffril et al. (2018) categorised these practices into different forms such as crop management, 29 irrigation and water management, farm management, ffnancial management, physical infrastructure 30 management, and social activities. "Climate-smart agriculture" - an integrated approach for developing 31 agricultural strategies that address the intertwined challenges of food security and climate change – is 32 increasingly being promoted in many parts of the region, especially in Southeast and South Asia with 33 potentially promising outcomes (Chandra et al., 2017; Khatri-Chhetri et al., 2017; Shirsath et al., 2017; 34 Westermann et al., 2018; Wassmann et al., 2019b). Site specific adaptations such as those in Pakistan 35 include the farmers' utilisation of several adaptation techniques which include changing crop type and 36 variety and improving seed quality; fertiliser application and use of pesticides and plant shade trees; and 37 water storage and farm diversification (Fahad and Wang, 2018), as well as the implementation of a 38 comprehensive climate information services to farming communities (World Meteorological Organization, 39 2017). | 1908 - 190 | 'rot-Adapt-Mitig-Impa | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 39 40 There is medium evidence (low agreement) about the effectiveness of migration and planned relocation in 41 reducing risk exposure. Evidence on climate-driven internal migration shows that moving has mixed 42 outcomes on risk reduction and adaptive capacity. On one hand, migration can improve adaptive capacity by 43 increasing incomes and remittances as well as diversifying livelihoods (Maharjan et al., 2020). On the other, 44 migration can expose migrants to new risks. For example, in Bangalore (India), migrants often face high 45 exposure to localised flooding, insecure and unsafe livelihoods, and social exclusion, which collectively 46 shape their vulnerability (Byers et al., 2018);(Singh and Basu, 2020). In Metro Manila (Philippines) and 47 Chennai (India), planned relocations to reduce disaster risk have often exacerbated vulnerability, due to 48 relocation sites being in environmentally sensitive areas, inadequate livelihood opportunities, and exposure 49 to new risks (Ajibade, 2019; Jain et al., 2021) (Meerow, 2017). | 1922 - 192 | 'rot-Adapt-Mitig-Impa | INTANBILE | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 39 40 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 10 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 10-72 Total pages: 172 1 2 Figure 10.11: Projected health impacts due to climate change in Asia 3 4 5 The global estimates for increases in malaria and dengue deaths (annual estimates) are approximately 32,700 6 and 280 additional deaths, respectively, in 2050 under the medium-high emissions scenario (World Health 7 Organization, 2014). Among these additional deaths, 9,300 and 200 deaths, respectively, are projected to 8 occur in South Asia. The population at risk of malaria infection is estimated to increase by 134 million by 9 2030 in South Asia under the medium-high emissions scenario, considering socio-economic development. If 10 no actions are taken, malaria incidence in northern China is projected to increase by 69%–182% by 2050 11 (Song et al., 2016). Another study suggested a decrease in climate suitability for malaria in northern and 12 eastern India, southern Myanmar, southern Thailand, the Malaysia border region, Cambodia, eastern Borneo 13 and Indonesia by 2050 (Khormi and Kumar, 2016). By contrast, climate suitability for malaria is projected to 14 increase in the southern and south-eastern mainland of China and Taiwan, Province of China (Khormi and 15 Kumar, 2016). | 1926 - 192 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 20 Higher numbers of dengue fever cases are projected to occur under RCP 8.5 than RCP2.6 in China (Song et 21 al., 2017). Compared with the average numbers in 1997–2012, the annual number of days suitable for 22 dengue fever transmission in the 2020s, 2050s and 2080s will increase by 15, 25 and 40 days, respectively, 23 in south China under RCP8.5. In addition, areas in which year-round dengue fever epidemics occur will likely increase by 4500, 8800 and 20,700 km2 24 in the 2020s, 2050s and 2080s, respectively, under RCP8.5 25 (Nahiduzzaman et al., 2015). | 1927 - 1927 | | | |
| IPCC_AR6_WGII_Full_Report | 41 42 Changing dietary patterns, particularly reducing red meat consumption and increasing fruit and vegetable 43 consumption, contributes to the reduced greenhouse gas emissions, as well as premature deaths. The 44 adoption of global dietary guidelines was estimated to avoid 5.1 million deaths per year relative to the 45 reference scenario, in which the largest number of avoidable deaths occurred in East Asia and South Asia, 46 and greenhouse gas emissions would be reduced most in East Asia (Springmann et al., 2016). In China, 47 dietary shifts to meet the national dietary reference intakes reduced the daily carbon footprint by 5-28% 48 depending on scenario (Song et al., 2017). In India, the optimised healthy diets (e.g., lower amounts of 49 wheat, and increased amounts of legumes) could help reduce up to 30% water use per person for irrigation 50 and reduce diet-related greenhouse gas emissions. This would result in 6,800 life-years gained per 100,000 51 population in 2050 (Milner et al., 2017). | 1928 - 1928 | | | |
| IPCC_AR6_WGII_Full_Report | 47 48 A study of Sylhet Division in Bangladesh, deploying knowledge quality assessment' (KQA) tool found 49 significant co-relation between a narrow technocratic problem framing, divorced from traditional knowledge 50 strongly rooted in local socio-cultural histories and relatively low project success due to skewed risk-based 51 calculation disconnected to the ground realities (Wani and Ariana, 2018) (Haque et al., 2017) while 52 highlighting the vulnerability of the Bajo tribal communities, inhabiting the coastal areas of Indonesia, to 53 climate change, share several examples of their Indigenous Knowledge and traditions of marine resource 54 conservation, and show how this wisdom, a valuable asset for climate adaptation governance, has been 55 passed from generation to generation through oral tradition. | 1931 - 193 | Prot-Adapt-Mitig-Impac | INTANBILE | INDG |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 32 33 10.5.2.2.4 Forests and Biodiversity 34 Technologies and its applications to identify habitat degradation, ecosystem functions and biodiversity 35 conservation are increasing in Asia, with many countries looking up to new and improved means for forest 36 and biodiversity monitoring and conservation. In particular, there has been an impressive use of temporal 37 satellite data, particularly from the Landsat and the MODIS series for widespread monitoring of forests and 38 ecological resources. These provided reliable information on forests and ecosystem services at country level, 39 in difficult terrains, such as the mountains, cross-boundaries and otherwise inaccessible areas. For instance, 40 Yin et al. (2017) estimated cross-boundary forest resources in Central Asia using remote sensing techniques, 41 a region which traditionally suffered from lack of reliable forest data. In a separate study, Reddy et al. (2020) 42 used long-term MODIS forest fire data from 2003–2017 to characterise fire frequency, density, and hotspots 43 in South Asia. Archival of scientific data, particularly helped the provisioning of scientific research, backed 44 by the state-of-the art modelling techniques, advance-computing methods and innovations in big data 45 analysis. A number of studies simulated forest futures from local to continent scale under different socio- 46 economic and climate scenarios. As for instance, at local scale, DasGupta et al. (2018) projected future 47 extent of mangroves in the Sundarban delta under four local scenarios, while Estoque et al. (2019) modelled 48 and developed spatial maps of regional forest futures in Southeast Asia using the five SSP scenarios. Science 49 and technology also helped the monitoring of species diversity and abundance, pivotal for sustaining 50 ecosystem and ecosystem based adaptation. Digital camera traps, radio-collaring methods have largely 51 replaced old film cameras and labour-intensive methods of photo-screening to count target species (Pimm et 52 al., 2015). This enhanced scientific capacities to monitor biodiversity and facilitate better conservation in 53 difficult terrains, control poachers and maintain steady ecological balance. Umapathy et al. (2016), for 54 example used VHF radio-collars and satellite-based tracking tools to monitor the movement of Bengal tigers 55 in hostile island terrain. Photo recognition and other non-invasive techniques for individual identification 56 have been rising in Asia. For example, a study by Gray et al. (2014) used fecal-DNA samples to estimate the 57 population density of Asian elephant in Cambodia. The advancement of citizen science programs has greatly ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 10 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 10-82 Total pages: 172 1 facilitated better monitoring of forest resources, including invasive floral and faunal species (Chandler et al., 2 2017; Johnson et al., 2020). In Asia, citizen science has been used effectively in India (Chandler et al., 3 2017), also in Malaysia for the monitoring the urban bird abundance (Puan et al., 2019). | 1936 - 193 | 'rot-Adapt-Mitig-Impa | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 7 8 Way forward: Developing robust metrics and institutions for measuring and reporting L&D at national and 9 regional scales, especially non-economic damages and L&D due to slow-onset events is critical. In addition 10 to vulnerability assessments, assessing L&D and limits to adaptation can inform adaptation prioritisation and 11 enhance adaptation effectiveness (e.g.(Craft and Fisher, 2016) (Leiter et al., 2019)). Lessons are available 12 from biodiversity and ecosystem services monitoring frameworks that have well-developed metrics and 13 processes (e.g., (Díaz et al., 2020)). | 1944 - 194 | 'rot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | 28 29 Risks are generally amplified for people without social protection or essential infrastructure and services, 30 and for people with limited access to land and quality housing, especially those in exposed areas and 31 informal settlements without secure tenure (ESCAP, 2017). Stateless people are disproportionately affected 32 by climate change and disasters as they tend to reside in hazard-prone areas and their statues as non-citizens 33 often limits access to assistance (Connell, 2015). The three main types of social protection, namely (i) social 34 safety nets (also known as social assistance), which include conditional and unconditional cash transfers, 35 public work programs, subsidies, and food stamps; (ii) social insurance, which consists of contributory 36 pensions and contributory health insurance; and (iii) labour market measures, which include instruments 37 such as unemployment compensation (Bank, 2018b). The potential for an integrated adaptive social 38 protection is not yet harnessed by policymakers in tackling the structural causes of vulnerability to climate 39 change (Tenzing, 2019). Public works program, i.e. India's MGNREGA should take into account climate 40 risk in planning and support development of community assets to increase collective resilience. | 1948 - 194 | 'rot-Adapt-Mitig-Impa | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 33 This will have major implications for SP systems and therefore national SP strategies should be designed to 34 anticipate and address climate-induced internal mobility (Schwan and Yu, 2017). For instance, it does not 35 offer a solution for maintaining Indigenous culture often strongly affected or even disrupted by climate 36 change (Olsson, 2014). Hence, an effective approach needs to combine different policy instruments to 37 support protection, adaptation and migration (O'Brien et al., 2018). | 1949 - 194 | 'rot-Adapt-Mitig-Impa | | INDG |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | (Mistry and Berardi, 2016; Roder et al., 2016) ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 10 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 10-98 Total pages: 172 from the perspective of Indigenous Knowledge and then seeking relevant scientific knowledge Empowering younger generation to ensure continuity of Indigenous cultures and theirlinked ecosystems. | 1952 - 1953 | | | INDG |
| IPCC_AR6_WGII_Full_Report | (2020) in Philippines Carefully planned resettlement and migration (including decongestion of urban areas) Inadequate evidence to make an assessment SDGs 8, 10, 11 SDGs 6, 10, 11 (Arnall, 2019) in Asia; (Maharjan et al., 2020) in South Asia; (Estoque et al., 2020) in the Philippines; Banerjee et al. (2019) in Nepal Aquifer storage and recovery Low synergy SDGs 6, 12 (Lopez et al., 2014) in Saudi Arabia; (Hoque et al., 2016) in South and SE Asia Nature-based solutions in urban areas: green infrastructure (including urban green space, blue-green infrastructure) High synergy Blue-green infrastructure act as carbon sinks SDGs 3, 9, 11 (Mabon et al., 2019) in Japan; (Estoque et al., 2020) in the Philippines; (Byrne et al., 2015) and (Zhang et al., 2020a) in China; (Mabon and Shih, 2018) in Taiwan, Province of China; (Liao, 2019) and (Radhakrishnan et al., 2019) in Singapore Coastal green infrastructure High synergy SDGs 9, 11, 13, 14, 15 (Sovacool et al., 2012), (Chow, 2018) and (Zinia and McShane, 2018) in Bangladesh; (Koh and ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 10 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 10-100 Total pages: 172 Teh, 2019) and (Herbeck and Flitner, 2019) in SE Asia; (Giffin et al., 2020) in Asia 1 Table Notes: a 2 Expert judgement b 3 Climate change adaptation options in the agricultural sector include soil management, crop diversification, cropping 4 system optimisation, and management, water management, sustainable land management, crop pest and disease 5 management, and direct seeding of rice (Aryal et al., 2020b). Other specific agricultural practices that have adaptation 6 and mitigation synergies include between tillage and residue management, alternate wetting and drying, site-specific 7 nutrient management, crop diversification to less water-intensive crops such as maize, and improved livestock 8 management (Aryal et al., 2020a). c 9 Risk management strategies in agriculture include crop insurance, index insurance, social networking and 10 community-based adaptation, collective international action, and integrated agro-meteorological advisory services 11 (Aryal et al., 2020b). | 1954 - 195 | 'rot-Adapt-Mitig-Impa | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 11 12 10.6.2.3 Knowledge Gaps 13 14 Adaptation follows knowledge on risks, and literature exists that systematically identifies and characterises 15 exposure and vulnerability, but gaps still exist. Decision making under uncertainty is challenged by the lack 16 of data for adapting to current and uncertain future climate, the different perceptions of risk, and the potential 17 solutions across different cultures and languages (van der Keur et al., 2016). Lack of downscaled climatic 18 data, diverse institutional structures, and missing links in policies, are among the challenges in South Asia 19 (Mall et al., 2019). In agriculture, there are gaps in the use of advanced farming techniques such as drought- 20 resistant crops, and information on climate change to support farming households in making adaptation 21 decisions (Akhtar et al., 2019; Khanal et al., 2019; Ullah et al., 2019). Better understanding of effective 22 water management is crucial due to conflicts for shared water in ARA (Shaban and Hamze, 2017; UNDP, 23 2018). For delta regions, gaps identified are methodologies and approaches appropriate for understanding 24 social vulnerability at various scales, pathways required for adaptation policy and response in the deltas that 25 transcend development, and the lessons from implemented policy and how practice can build on these 26 lessons in the deltas, among others (Lwasa, 2015). Approaches in tackling the challenges of climate change 27 and disasters in the cities of developing countries could be better understood, and shared between cities so 28 they can learn from one another (Filho et al., 2019). | 1957 - 195 | 'rot-Adapt-Mitig-Impa | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 17 18 Asia exhibits tremendous variation in terms of ecosystems, economic development, cultures, and climate risk 19 exposure. Mirroring this variation, households, communities, and governments have a wide range of coping 20 and adaptation strategies to deal with changing climatic conditions, with co-benefits for various non-climatic 21 issues such as poverty, conflict, and livelihood dynamics. | 1961 - 196 | 'rot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 10 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 10-161 Total pages: 172 1 Song, G. et al., 2017: Dietary changes to mitigate climate change and benefit public health in China. Science of The 2 Total Environment, 577, 289-298, doi:https://doi.org/10.1016/j.scitotenv.2016.10.184. | 2015 - 201 | Prot-Adapt-Mitig- | INTANBILE | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 33 Nuisance and extreme coastal flooding have increased due to sea-level rise superimposed upon high tides 34 and storm surges in low-lying coastal and estuarine locations, including impacts on cultural sites, traditions 35 and lifestyles of Aboriginal and Torres Strait Islander Peoples in Australia and Tangata Whenua Māori in 36 New Zealand. Droughts have caused financial and emotional stress in farm households and rural 37 communities. Tourism has been negatively affected by coral bleaching, fires, poor ski seasons and receding 38 glaciers. Governments, business and communities have experienced major costs associated with extreme 39 weather, droughts and sea-level rise. {11.3, 11.4, 11.5.2, Table 11.2, Boxes 11.1-11.6} 40 41 Climate impacts are cascading and compounding across sectors and socio-economic and natural 42 systems (high confidence). Complex connections are generating new types of risks, exacerbating existing 43 stressors and constraining adaptation options. An example is the impacts that cascade between 44 interdependent systems and infrastructure in cities and settlements. Another example is the 2019-2020 south- 45 eastern Australian wildfires which burned 5.8 to 8.1 million hectares, with 114 listed threatened species 46 losing at least half of their habitat and 49 losing over 80%, over 3,000 houses destroyed, 33 people killed, a 47 further 429 deaths and 3230 hospitalizations due to cardiovascular or respiratory conditions, $1.95 billion in 48 health costs, $2.3 billion in insured losses, and $3.6 billion in losses for tourism, hospitality, agriculture and 49 forestry. {11.5.1, Box 11.1} 50 51 Increasing climate risks are projected to exacerbate existing vulnerabilities and social inequalities and 52 inequities (high confidence). These include inequalities between Indigenous and non-Indigenous Peoples, 53 and between generations, rural and urban areas, incomes and health status, increasing the climate risks and 54 adaptation challenges faced by some groups and places. Resultant climate change impacts include the 55 displacement of some people and businesses, and threaten social cohesion and community wellbeing. | 2030 - 203 | rot-Adapt-Mitig-Impa | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 15 16 Australia's economy is dominated by financial and insurance services, education, mining, construction, 17 tourism, health care and social assistance (ABS, 2018) with Australian exports accruing mostly from mining 18 (ABS, 2018; ABS, 2019). In New Zealand, service industries, including tourism, collectively account for 19 around two thirds of GDP (NZ Treasury, 2016). The primary sector contributes 6% of New Zealand's GDP 20 and over half of the country's export earnings (NZ Treasury, 2016). | 2034 - 2034 | | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 11 12 13 14 Figure 11.1: Observed temperature changes in Australia and New Zealand. Annual temperature change time-series are 15 shown for 1910–2019. Mean annual temperature trend maps are shown for 1960–2019 using contours for Australia and 16 individual sites for New Zealand. Data courtesy of BoM and NIWA. | 2037 - 2037 | | | |
| IPCC_AR6_WGII_Full_Report | 17 18 19 20 Figure 11.2: Observed rainfall changes in Australia and New Zealand. Rainfall change time-series for 1900–2019 are 21 shown for northern Australia (December-February: DJF), southwest Australia (June-August: JJA) and southeast ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 11 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 11-11 Total pages: 151 1 Australia (JJA). Dashed lines on the maps for Australia show regions used for the time-series. Rainfall trend maps are 2 shown for 1960–2019 (DJF and JJA) using contours for Australia and individual sites for New Zealand. Areas of low 3 Australian rainfall (less than 0.25 mm/day) are shaded white in JJA. Data courtesy of BoM and NIWA. | 2037 - 2038 | | | |
| IPCC_AR6_WGII_Full_Report | Sea surface temperature Increased by 0.2°C/decade from 1981–2018. (MfE, 2020a) Air temperature extremes Number of frost days (below 0 degrees Celsius) decreased at 12 of 30 sites, the number of warm days (over 25°C) increased at 19 of 30 sites, and the number of heatwave days increased at 18 of 30 sites during 1972–2019. Increase in the frequency of hot February days exceeding the 90th percentile between 1980– 1989 and 2010–2019, with some regions showing more than a five-fold increase. | 2040 - 2040 | | | |
| IPCC_AR6_WGII_Full_Report | (NIWA, 2019; Salinger et al., 2019b; Salinger et al., 2020; Oliver et al., 2021) Rainfall From 1960–2019, almost half of the 30 sites had an increase in annual rainfall (mostly in the south) and 10 sites (mostly in the north) had a decrease, but few of the trends are statistically significant. Rainfall increased by 2.8% per decade in Whanganui, 2.1% per decade in Milford Sound and 1.3% per decade in Hokitika. Rainfall decreased by 4.3% per decade in Whangarei and 3.2% per decade in Tauranga. | 2040 - 2040 | | | |
| IPCC_AR6_WGII_Full_Report | (MfE, 2020a) Rainfall extremes The number of days with extreme rainfall increased at 14 of 30 sites and decreased at 11 sites from 1960–2019. Most sites with increasing annual rainfall had more extreme rainfall and most sites with decreasing annual rainfall had less extreme rainfall. | 2040 - 2040 | | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | (MfE, 2020a) Drought Drought frequency increased at 13 of 30 sites from 1972–2019 and decreased at 9 sites. Drought intensity increased at 14 sites, 11 of which are in the north, and decreased at 9 sites, 7 of which are in the south. | 2040 - 2040 | | | |
| IPCC_AR6_WGII_Full_Report | (MfE, 2020a) Windspeed Since 1970, the wind belt has often been shifted to the south of New Zealand, bringing an overall decrease in wind-speed over the country. For 1980–2019, the annual maximum wind gust decreased at 11 of the 14 sites that had enough data to calculate a trend, and increased at 2 of the 14 sites (MfE, 2020a) Sea-level rise Increased 1.8 mm/year from 1900–2018 and 2.4 mm/year from 1961–2018, mostly due to climate change. | 2040 - 2040 | | | |
| IPCC_AR6_WGII_Full_Report | (Bell and Hannah, 2019) Fire Six of 28 sites (Napier, Lake Tekapo, Queenstown, Gisborne, Masterton, and Gore) had an increase in days with very high or extreme fire danger from 1997–2019 and 6 sites (Blenheim, Christchurch, Nelson, Tara Hills, Timaru, and Wellington) had a decrease. An increase in fire impacts from 1988–2018 included homes lost, damaged, threatened and evacuated. | 2040 - 204 | Impact | | |
| IPCC_AR6_WGII_Full_Report | Ecosystem Climate-related Pressure Impact Source Australia Forest and woodlands of southern and southwestern Australia 30-year declining rainfall Drought-induced canopy dieback across a range of forest and woodland types (e.g. northern jarrah) (Matusick et al., 2018; Hoffmann et al., 2019) Multiple wildfires in short succession resulting from increased fire risk conditions including declining winter rainfall and increasing hot days Local extirpations and replacement of dominant canopy tree species and replacement by woody shrubs due to seeders having insufficient time to reach reproductive age (Alpine Ash) or vegetative regeneration capacity is exhausted (Snow Gum woodlands) (Slatyer, 2010; Bowman et al., 2014; Fairman et al., 2016; Harris et al., 2018; Zylstra, 2018) Background warming and drying created soil and vegetation conditions that are conducive to fires being ignited by lightning storms in regions that have rarely experienced fire over the last few millennia Death of fire sensitive trees species from unprecedented fire events (Palaeo-endemic pencil pine forest growing in sphagnum, Tasmania, killed by lightning-ignited fires in 2016) (Hoffmann et al., 2019) Australia Alps Bioregion and Tasmanian alpine zones Severe winter drought; warming and climate-induced biotic interactions Shifts in dominant vegetation with a decline in grasses and other graminoids and an increase in forb and shrub cover in Bogong High Plains, Victoria, Australia (Bhend et al., 2012; Hoffmann et al., 2019) ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 11 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 11-21 Total pages: 151 Snow loss, fire, drought and temperature changes Changing interactions within and among three key alpine taxa related to food supply and vegetation habitat resources: The mountain pygmy-possum (Burramys parvus), the mountain plum pine (Podocarpus lawrencei) and the bogong moth (Agrostis infusia) (Hoffmann et al., 2019) Retreat of snow line Increased species diversity in alpine zone (Slatyer, 2010) Reduced snow cover Loss of snow-related habitat for alpine zone endemic and obligate species (ACE CRC, 2010; Pepler et al., 2015a; Thompson, 2016; Mitchell et al., 2019) Wet Tropics World Heritage Area Warming and increasing length of dry season Some vertebrate species have already declined in both distribution area and population size, both earlier and more severely than originally predicted (Moran et al., 2014; Hoffmann et al., 2019) Sub-Antarctic Macquarie island Reduced summer water availability for 17 consecutive summers, and increases in mean wind speed, sunshine hours and evapotranspiration over four decades Dieback in the critically endangered habitat-forming cushion plant Azorella macquariensis in the fellfield and herb field communities (Bergstrom et al., 2015; Hoffmann et al., 2019) Mass mortality of wildlife species (flying foxes, freshwater fish) Extreme heat events; rising water temperatures, temperature fluctuations, altered rainfall regimes including droughts and reduced in-flows flying foxes - thermal tolerances of species exceeded; fish - amplified extreme temperature fluctuations, increasing annual water basin temperatures, extreme droughts and reduced runoff after rainfall (AAS, 2019; Ratnayake et al., 2019; Vertessy et al., 2019) Bramble Cay melomys (mammal) Melomys rubicola Sea-level rise and storm surges in Torres Strait Loss of habitat and global extinction (Lunney et al., 2014; Gynther et al., 2016; Waller et al., 2017; CSIRO, 2018) Koala, Phascolarctos cinereus Increasing drought and rising temperatures, compounding impacts of habitat loss, fire and increasing human population Population declines | 2047 - 204 | Impact | | INDG |
| IPCC_AR6_WGII_Full_Report | 22 23 Improved coastal modelling, experiments and in situ studies are reducing uncertainties at a local scale about 24 the impact of future sea-level rise on coastal freshwater terrestrial wetlands (medium confidence) (Shoo et 25 al., 2014; Bayliss et al., 2018; Grieger et al., 2019). Low-lying coastal wetlands are susceptible to saltwater 26 intrusion from sea-level rise (Shoo et al., 2014; Kettles and Bell, 2015; Finlayson et al., 2017) with 27 consequences for species dependent on freshwater habitats (Houston et al., 2020). Saline habitat conditions 28 will move inland and new coastal ecosystem states may emerge, including the World Heritage listed 29 Kakadu's freshwater wetland (Bayliss et al., 2018) (Table 11.5). Increasingly, sea-level rise will shrink the 30 intertidal zone, having implications for wading birds which use this zone (Tait and Pearce, 2019) (Box 11.6). | 2050 - 205 | Impact | | |

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| Report Title (Year) | Quotation Content | Page(s) | Prot-Adapt-Mitig-Impact* | Intangible** | Indigenous*** |
|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 32 33 The Australian wildfires of 2019–2020 resulted in 33 deaths, over 3,000 houses destroyed, $2.3 billion in 34 insured losses, and $3.6 billion in losses for tourism, hospitality, agriculture and forestry (CoA, 2020e; 35 Filkov et al., 2020) (Figure Box 11.1.2). Smoke caused a further 429 deaths and 3230 hospitalizations as a 36 result of respiratory distress and illness, with health costs totalling $1.95 billion (Johnston et al., 2020). | 2055 - 205 | Impact | | |
| IPCC_AR6_WGII_Full_Report | Communications Clearer communication of existing exposure and vulnerability to enable informed decisions about risk tolerance and management. This should include sites of key biodiversity that are sensitive or susceptible to fire. | 2058 - 205 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 16 17 The marine environment is important to the culture, health and well-being of the region's diverse Indigenous 18 Peoples, including those who had sovereign ownership, governance, resource rights, and stewardship over 19 'Sea Country' for many thousands of years before the current sea level stabilised approximately 6000 years 20 ago and before current coastal ecosystems were established (Rist et al., 2019). Marine environments ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 11 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 11-32 Total pages: 151 1 contribute A$69 billion per year to Australia's economy (Eadie et al., 2011), and NZ$4 billion per year to 2 New Zealand's economy (MfE, 2016). They have a high proportion of rare and endemic species (Croxall et 3 al., 2012) and provide ecosystem services including food production, coastal protection, tourism and carbon 4 sequestration (Croxall et al., 2012; Kelleway et al., 2017). Half of the species within New Zealand's seas are 5 endemic (Costello et al., 2010b). | 2058 - 205 | Prot-Adapt-Mitig- | | INDG |
| IPCC_AR6_WGII_Full_Report | 35 36 In 2016 and 2017, the Great Barrier Reef (GBR) experienced consecutive occurrences of the most severe 37 coral bleaching in recorded history (very high confidence) (Box 11.2), with shallow-water reef in the top two 38 thirds of the GBR affected and the severity of bleaching on individual reefs tightly correlated with the level 39 of local heat exposure (Hughes et al., 2018b; Hughes et al., 2019c). Mass mortality of corals from these two 40 unprecedented events resulted in larval recruitment in 2018 declining by 89% compared to historical levels 41 (Hughes et al., 2019b). Southern reefs were also affected by warming, although significantly less than in the 42 north (Kennedy et al., 2018). Coral reefs in Australia are at very high risk of continued negative effects on 43 ecosystem structure and function (Hughes et al., 2019b) (very high confidence), cultural well-being 44 (Goldberg et al., 2016; Lyons et al., 2019) (very high confidence), food provision (Hoegh-Guldberg et al., 45 2017) (medium confidence), coastal protection (Ferrario et al., 2014) (high confidence) and tourism (Deloitte 46 Access Economics, 2017; Prideaux and Pabel, 2018; GBRMPA, 2019) (high confidence). If bleaching 47 persists, an estimated 10,000 jobs and A$1 billion in revenue would be lost per year from declines in tourism 48 alone (Swann and Campbell, 2016). | 2059 - 205 | 'rot-Adapt-Mitig-Impac | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 49 50 11.3.2.2 Projected Impacts 51 52 Future ocean warming, coupled with periodic extreme heat events, is projected to lead to the continued loss 53 of ecosystem services and ecological functions (high confidence) (Smale et al., 2019), as species further shift 54 their distributions and/or decline in abundance (Day et al., 2018). Compounding climate-driven changes in 55 the distribution of habitat forming species, invasive macroalgae are predicted to exhibit higher growth under 56 all higher pCO2 and lower pH conditions (Roth-Schulze et al., 2018). Corals and mangroves around northern 57 Australia and kelp and seagrass around southern Australia are of critical importance for ecosystem structure ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 11 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 11-33 Total pages: 151 1 and function, fisheries productivity, coastal protection and carbon sequestration; these ecosystem services are therefore extremely likely2 2 to decline with continued warming. Equally, many species provide important 3 ecosystem structure and function in New Zealand's seas including in the deep sea (Tracey and 4 Hjorvarsdottir, 2019). The future level of sustainable exploitation of fisheries is dependent on how climate 5 change impacts these ecosystems. Native kelp is projected to further decline in south-eastern New Zealand 6 with warming seas (Table 11.6). Climate change could affect New Zealand fisheries' productivity 7 (Cummings et al., 2021), and both ocean warming and acidification may directly affect shellfish culture 8 (Cunningham et al., 2016; Cummings et al., 2019), and indirectly through changes in phytoplankton 9 production (Pinkerton, 2017). | 2059 - 206 | 'rot-Adapt-Mitig-Impac | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 43 44 11.3.2.3 Adaptation 45 46 Climate change adaptation opportunities and pathways have been identified across aquaculture, fisheries, 47 conservation and tourism sectors in the region (MacDiarmid et al., 2013; Fleming et al., 2014; MPI, 2015; 48 Jennings et al., 2016; MfE, 2016; Royal Society Te Apārangi, 2017; Ling and Hobday, 2019) and some 49 stakeholders are already autonomously adapting (Pecl et al., 2019). Some fishing and aquaculture industries 50 use seasonal forecasts of environmental conditions, to improve decision making, risk management, and 51 business planning (Hobday et al., 2016) with potential to use 5-yearly forecasts similarly (Champion et al., 52 2019). Shifts in the distribution, and availability of target species (e.g., oceanic tuna) would impact the 2 In this Report, the following summary terms are used to describe the available evidence: limited, medium, or robust; and for the degree of agreement: low, medium, or high. A level of confidence is expressed using five qualifiers: very low, low, medium, high, and very high, and typeset in italics, e.g., medium confidence. For a given evidence and agreement statement, different confidence levels can be assigned, but increasing levels of evidence and degrees of agreement are correlated with increasing confidence. | 2060 - 206 | ›rot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | Loss of kelp Australia-wide totalling at least 140,187 ha Ocean warming & change in East Australian Current (lower nutrients) (Wahl et al., 2015; Butler et al., 2020; Filbee-Dexter and Wernberg, 2020) Regional loss of seagrass in Shark Bay World Heritage Area, Western Australia High air and water temperatures during 2011 heatwave (Strydom et al., 2020) Increased annual dugong and inshore dolphin mortality across Queensland Sustained low air temperature and increased freshwater discharge during high SOI (ENSO) index (Meager and Limpus, 2014) Predict equatorward decline and poleward shift of sea urchin in eastern Australia Ocean warming (Castro et al., 2020) Increasing mortality of Australian fur seal pups in low-lying colonies Storm surges and high tides amplified by ongoing sea�level rise (McLean et al., 2018) (Box 11.6) Rapid shifts in community composition, structure and integrity Community-wide tropicalization in Australian temperate reef communities. Temperate species replaced by seaweeds, invertebrates, corals, and fishes characteristic of subtropical and tropical waters Extreme marine heatwaves led to a 100-km range contraction of extensive kelp forests (Vergés et al., 2016; Wernberg et al., 2016) On-going declines in habitat-forming seaweeds Dieback of temperate seagrass in Shark Bay, Australia, subsequently replaced by a tropical early successional seagrass with seagrass�associated megafauna (sea turtles) declining in health status Climate-driven shift of tropical herbivores 2011 Marine heatwave (Thomson et al., 2015; Nowicki et al., 2017; Zarco�Perello et al., 2017) (Wernberg et al., 2016) (Strydom et al., 2020) Increased herbivory by fish on tropicalized reefs of Western Australia Change in species composition due to ocean warming (Zarco-Perello et al., 2019) No recovery two years after coral bleaching and macro alga mortality in western Australia 2011 marine heatwave (Bridge et al., 2014) ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 11 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 11-37 Total pages: 151 Mass mortality of particular coral species on affected reefs during heatwaves on the Great Barrier Reef (eastern Australia) led to altered coral reef structure and species composition 8 months later. | 2063 - 2064 | | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 2016 marine heatwave 2016 Marine heatwave (Hughes et al., 2018c) (Stuart-Smith et al., 2018) New Zealand Changes in life-history Alteration of the shell of pāua (black footed abalone, Haliotis iris) under lowered pH (calcite layer thinner, greater etching of external shell surface) Decline in maximum swimming performance of kingfish and snapper Increased mortality and faster growth in juvenile kingfish Lowered pH (experimental laboratory study) Elevated CO2 (experimental laboratory study) Increased temperature (Cummings et al., 2019) (Watson et al., 2018; McMahon et al., 2020) (Watson et al., 2018) Earlier spawning of snapper in South Island 2017–2018 heatwave (Salinger et al., 2019b) Increase in mortality Heat stress mortality in salmon farms off Marlborough, New Zealand, where 20 % of the salmon stocks died 2017–18 marine heatwave (Salinger et al., 2019b) Changes in species distributions Species increasingly caught further south, e.g. snapper and kingfish Ocean warming and 2017–2018 marine heatwave (Salinger et al., 2019b) Non-breeding distribution of New Zealand nesting seabird (Antarctic Prion) shifting south with long term climate inferred from stable isotopes Climate warming (Grecian et al., 2016) Less phytoplankton production in Tasman Sea but more on subtropical front Ocean warming (Chiswell and Sutton, 2020) Loss of bull kelp (Durvillaea) populations in southern New Zealand subsequently replaced by the introduced kelp Undaria 2017-18 heatwave when sea and air temperatures exceeded 23 and 30 ° C respectively (Salinger et al., 2019b; Thomsen et al., 2019; Salinger et al., 2020) 1 2 3 [START BOX 11.2 HERE] 4 5 Box 11.2: The Great Barrier Reef in Crisis 6 7 The Great Barrier Reef ("GBR") is the world's largest coral reef system, comprising 3,863 reefs over an area of 348,700 km2 8 , stretching for 2,300 km. The GBR is a central cornerstone of the beliefs, knowledges, Lores, 9 languages and ways of living for over 70 geographically and culturally diverse Traditional Owner groups ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 11 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 11-38 Total pages: 151 1 spanning the length of the GBR (Dale et al., 2018), and contributes an estimated A$6.4 billion per year (pre 2 COVID) to the Australian economy, mainly via tourism. As the world's most extensive coral reef ecosystem, 3 GBR is a globally outstanding and significant entity, with practically the entire ecosystem inscribed as World 4 Heritage in 1981 (UNESCO, 2021). | 2064 - 2065 | | | |
| IPCC_AR6_WGII_Full_Report | 41 42 Tourist motivations for visiting the GBR are changing, with a recent survey finding that two-thirds of 43 tourists were visiting 'before it was gone' and a similar number were reporting damage to the reef – an 44 example of 'last chance tourism' (Piggott-McKellar and McNamara, 2016). The Australian Government is 45 investing A$1.9 billion to support the Great Barrier Reef through science and practical environmental 46 outcomes including reducing other anthropogenic pressures which can suppress natural adaptive capacity 47 (CoA, 2019b; GBRMPA, 2019). However, adaptation efforts on the Great Barrier Reef aimed specifically at 48 climate impacts, for example, coral restoration following marine heatwave impacts (Boström-Einarsson et 49 al., 2020) may slow the impacts of climate change in small discrete regions of the reef, or reduce short-term 50 socio-economic ramifications, but will not prevent widespread bleaching (Condie et al. 2021). | 2065 - 206 | 'rot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGII_Full_Report | 33 34 11.3.4.1.2 Projected impacts 35 Australian crop yields are projected to decline due to hotter and drier conditions, including intense heat 36 spikes (Anwar et al., 2015; Lobell et al., 2015; Prokopy et al., 2015; Dreccer et al., 2018; Nuttall et al., 2018; 37 Wang et al., 2018a) (high confidence). Interactions of heat and drought could lead to even greater losses than 38 heat alone (Sadras and Dreccer, 2015; Hunt et al., 2018). Australian wheat yields are projected to decline by 39 2050, with a median yield decline of up to 30% in south-west Australia and up to 15% in South Australia, 40 with possible increases and decreases in the east (Taylor et al., 2018, Wang, #1599; Wang et al., 2018a). In 41 temperate fruit, accumulated winter chill for horticulture is projected to further decline (Darbyshire et al., 42 2016). Winegrape maturity is projected to occur earlier due to warmer temperatures (Webb et al., 2014; van 43 Leeuwen and Darriet, 2016; Jarvis et al., 2018; Ausseil et al., 2019b) (high confidence) leading to potential 44 changes in wine style (Bonada et al., 2015). Rice is susceptible to heat stress and average grain yield losses 45 across rice varieties range from 83% to 53% in experimental trials when heat stress was applied during plant 46 emergence and grain fill stages (Ali et al., 2019). In Tasmania, wheat yields are projected to increase, 47 particularly at sites presently temperature-limited (Phelan et al., 2014). | 2074 - 207 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 26 27 Key infrastructure and services face major challenges. Structural metal corrosion rates are projected to 28 increase significantly at coastal locations but decrease inland (Trivedi et al., 2014). A drier climate may 29 decrease the rate of deterioration of road pavements but extreme rainfall events and heat pose a significant 30 risk (Taylor and Philp, 2015), especially to unsealed roads in northern Australia (CoA, 2015). Critical 31 infrastructure on coasts is at risk from sea-level rise and storm surges (Box 11.6). Facilities such as hospitals 32 face weather-related hazards exacerbated by climate change and not originally anticipated in building and 33 infrastructure design (Loosemore et al., 2011; Loosemore et al., 2014). By 2050, increased risks are 34 projected for the availability and quality of potable water supplies, delivery of wastewater and stormwater 35 services to communities, transport systems, electricity infrastructure, operating municipal landfills, and 36 contaminated sites located near rivers and the coast (Gilpin et al., 2020; MfE, 2020a; Hughes et al., 2021). | 2081 - 208 | Impact | | |

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| --- | --- | --- | --- | --- | --- |
| IPCC_AR6_WGII_Full_Report | Sector Key Risks Adaptation Options Inter-Sector Dependencies Sources Road Heat; sea-level rise; coastal surges; floods and high intensity rainfall impacts on road foundations Re-routing; coastal protection; improved drainage Ports (fuel supply); rail (fuel supply); electricity (NCCARF, 2013; CoA, 2018a; MfE, 2020a) Rail Extreme temperatures; flooding; sea-level rise; high intensity rainfall impacts on track foundations Drainage and ventilation improvements; systematic risk assessments; overhead wire and rail/sleeper upgrades; rerouting Electricity; telecommunications; fuel supply (transport, ports) (CoA, 2018a; MfE, 2020a) Urban and Rural Built Environment1 Extreme temperatures; floods; extreme weather events; wildfire (at urban-rural interface); sea-level rise Multiple options from the building-to-city scale to reduce heat impacts and improve climate resilience; behavioural change; coastal defences and managed retreat Road; rail; electricity; air and seaports; telecommunications; water and wastewater (CoA, 2018a; Newton et al., 2018; Haddad et al., 2019; MfE, 2020a; Paulik et al., 2020; Tapper, In Press) (Box 11.4) (Box 11.4) ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 11 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 11-56 Total pages: 151 Electricity High wind/ temperature events; wildfire; lightning; dust storms; drought (hydro) Demand management; re-engineering and new technology; network intelligence; smart metering; improved planning for outages Road; rail; water (CoA, 2017; MfE, 2020a) (11.3.10.) Ports: Air and Sea Sea-level rise; coastal surges; wind; heat; extreme weather events Air; improved coastal, pluvial and fluvial flood protection, on�site services. Sea; widening operational limits, raising wharfs, roads and breakwaters. | 2082 - 208 | Prot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGII_Full_Report | 32 33 34 [START BOX 11.6 HERE] 35 36 Box 11.6: Rising to the Sea-Level Challenge 37 38 Many of the region's cities and settlements, cultural sites and place attachments are situated around harbours, 39 estuaries and lowland rivers (Black, 2010; PCE, 2015; Australia SoE, 2016; Rouse et al., 2017; Hanslow et 40 al., 2018; Birkett-Rees et al., 2020) exposed to ongoing relative sea-level rise (RSLR). RSLR includes 41 regional variability in oceanic conditions (Zhang et al., 2017) and vertical land movement along New 42 Zealand's tectonically dynamic coasts (Levy et al., 2020) and some Australian hotspots for subsidence 43 (Denys et al., 2020; King et al., 2020; Watson, 2020). | 2084 - 2084 | | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 44 45 46 Table Box 11.6.1: Observed and projected impacts from higher mean sea level Impacts from increase in mean sea level References Nuisance and extreme coastal flooding have increased from higher mean sea level in New Zealand. Projected sea level rise will cause more frequent flooding in Australia and New Zealand before mid-century (very high confidence) (Hunter, 2012; McInnes et al., 2016; Stephens et al., 2017; Stephens et al., 2020) (Steffen et al., 2014; PCE, 2015; MfE, 2017a; Hague et al., 2019; Paulik et al., 2020) Squeeze in intertidal habitats (high confidence) (Steffen et al., 2014; Peirson et al., 2015; Mills et al., 2016a; Mills et al., 2016b; Pettit et al., 2016; Rouse et al., 2017; Rayner et al., 2021) ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 11 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 11-58 Total pages: 151 Significant property and infrastructure damage (high confidence) (Steffen et al., 2014; PCE, 2015; Harvey, 2019; LGNZ, 2019; Paulik et al., 2020) (Table Box 11.5.2) (Table Box 11.6.2) Loss of significant cultural and archaeological sites and projected to compound with several hazards over this century (medium confidence) (Bickler et al., 2013; Birkett-Rees et al., 2020; NZ Archaeological Association, 2020) Increasing flood risk and water insecurity with health and well�being impacts on Torres Strait Islanders (high confidence) (Steffen et al., 2014; McInnes et al., 2016; McNamara et al., 2017) Degradation and loss of freshwater wetlands (high confidence) (Pettit et al., 2016; Bayliss and Ligtermoet, 2018; Tait and Pearce, 2019; Grieger et al., 2020; Swales et al., 2020) 1 2 3 Coastal shoreline position is driven by a complex combination of natural drivers, past and present human 4 interventions, climate variability (Bryan et al., 2008; Helman and Tomlinson, 2018; Allis and Murray Hicks, 5 2019) and variation in sediment flux (Blue and Kench, 2017; Ford and Dickson, 2018). RSLR, to date, is a 6 secondary factor influencing shoreline stability (medium confidence), and in Australia no definitive sea-level 7 rise signature is yet observed in shoreline recession, nor documented in New Zealand, due to variability in 8 shoreline position responding to storms and seasonal, annual and decadal climate drivers (Australian 9 Government, 2009; McInnes et al., 2016; Sharples et al., 2020). | 2084 - 208 | Impact | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 17 18 11.3.7 Tourism 19 20 11.3.7.1 Observed Impacts 21 22 Tourism is a major economic driver in the region, accounting for 3% (Australia) and 6% (New Zealand) of 23 GDP pre-COVID-19 (WTTC, 2018). Climate change is having significant impacts on tourism due to the 24 heavy reliance of the sector on natural heritage and outdoor attractions (11.3.1; Box 11.2). Furthermore, as 25 Australia and New Zealand are both long-haul destinations, a global increase in 'flygskam' (flight shame) 26 will to impact travel patterns (Becken et al., 2021). | 2090 - 209 | Impact | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 27 28 Impacts of climate change are being observed across the tourism system (Scott et al., 2019a) (high 29 confidence), most notably the Great Barrier Reef (Box 11.2) (Ma and Kirilenko, 2019). Australia's ski 30 industry is very sensitive to climatic change, due to reduction in snow depth and the length of the snow 31 season (Table 11.2) (Steiger et al., 2019; Knowles and Scott, 2020). The 2019-2020 summer wildfires (Box 32 11.1), impacted tourism and travel infrastructure, affecting air quality, vineyards and wineries (CoA, 2020e; 33 Filkov et al., 2020). Global media coverage of the wildfires, alongside Australia's climate change policy 34 response, profoundly and negatively, affected Australia's destination image (Schweinsberg et al., 2020; Wen 35 et al., 2020). In New Zealand's South Island, Fox and Franz Josef Glaciers have retreated approximately 36 700m since 2008, with ice melt and retreat resulting in increased rock fall risks and negatively affecting the 37 tourist experience (Purdie, 2013; Stewart et al., 2016; Wang and Zhou, 2019). The West Coast of New 38 Zealand is extremely prone to flooding events impacting amenity values and access (Paulik et al., 2019b). | 2090 - 209 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 39 Damage to tracks, huts and bridges have closed popular destinations, including the Hooker Glacier and the 40 popular Routeburn and Heaphy Tracks during heavy rainfall events (Christie et al., 2020). Climate-driven 41 damage is motivating 'last chance' tourism to see key natural heritage and outdoor attractions, e.g. Great 42 Barrier Reef (Piggott-McKellar and McNamara, 2016) and Franz and Fox Glaciers (Stewart et al., 2016). | 2090 - 209 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 43 44 11.3.7.2 Projected Impacts 45 46 Widespread impacts from projected climate change are very likely across the tourism sector. The World 47 Heritage listed Kakadu National Park in Australia is projected to experience increasing severity of cyclones 48 (Turton, 2014) and sea-level rise is projected to affect freshwater wetlands (11.3.1.2; Table 11.5) (McInnes 49 et al., 2015) and Indigenous rock art (Higham et al., 2016; Hughes et al., 2018a). The projected increase in 50 the number of hot days in northern and inland Australia may impact the attractiveness of the region for 51 tourists (Amelung and Nicholls, 2014; Webb and Hennessy, 2015). Coastal erosion and flooding of 52 Australasian beaches due to sea-level rise and intensifying storm activity is estimated to increase by 60% on 53 the Sunshine Coast by 2030 causing significant damage to tourist-related infrastructure (Hughes et al., 54 2018a). Urgent 'hard' and 'soft' adaptation strategies are projected to help reduce sea-level rise impacts 55 (Becken and Wilson, 2016). | 2090 - 209 | ʾrot-Adapt-Mitig-Impa | | INDG |
| IPCC_AR6_WGII_Full_Report | 56 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 11 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 11-64 Total pages: 151 1 Glacier tourism, a multimillion-dollar industry in New Zealand, is potentially under threat because glacier 2 volumes are projected to decrease (Purdie, 2013) (very high confidence). Glacier volume reductions of 50– 3 92% by 2099 relative to present reflect the large range of temperature projections between RCP2.6 and 4 RCP8.5. Under RCP2.6 at 2099, the glaciers retain a similar configuration to present, although clean-ice 5 glaciers will retreat significantly. For RCP4.5, RCP6.0 and RCP8.5, the clean-ice glaciers will retreat to 6 become small remnants in the high mountains (Anderson et al. 2021). | 2090 - 2091 | | | |
| IPCC_AR6_WGII_Full_Report | 7 8 Snow skiing faces significant challenges from climate change (high confidence). In Australia, the annual 9 maximum snow depth is estimated to decrease from current levels by 15% (2030) and 60% by 2070 (SRES 10 A2) (Di Luca et al., 2018). By 2070-2099, relative to 2000-2010, the length of the Victorian ski-season is 11 projected to contract by 65-90% under RCP8.5 (Harris et al., 2016). The New Zealand tourism destination of 12 Queenstown is expected to experience declining snowfall, increased wind and more severe weather events 13 (Becken and Wilson, 2016). Ski tourism stakeholders have been responding to longer-term climate risks with 14 an increase in snow-making machines in New Zealand since 2013 (Hopkins, 2015) and in Australia (Harris 15 et al., 2016). | 2091 - 209 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 25 26 With the exception of the ski industry (Becken, 2013; Hopkins, 2015), tourism stakeholders generally focus 27 on coping with short-term weather events, rather than longer-term climate risks, but do exhibit high adaptive 28 capacity by diversifying their activities (Stewart et al., 2016). Post Covid-19 pandemic economics and 29 recovery policies challenge this sector's prospects, and the combination of COVID-19 and climate change 30 (e.g. fires, floods) has also highlighted the need for the tourism sector to be able to respond to multiple, 31 overlapping crises. | 2091 - 209 | ʾrot-Adapt-Mitig-Impa | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 32 33 There is limited evidence that research into the impact of climate change on tourism in Australia and New 34 Zealand is translating into policy or action (Moyle et al., 2017). New Zealand government tourism sector 35 strategies acknowledge this and the need for greater understanding of climate change for the sector, (TIA, 36 2019), but do not offer solutions (MBIE, 2019b; MfE, 2020a). The COVID-19 pandemic and the global 37 pause of international travel offers an opportunity to potentially 'reset' tourism to account for the impacts of 38 climate change (Prideaux et al., 2020). | 2091 - 209 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 26 Climatic extremes increase the risk and impact of spillages along transportation routes (Grech et al., 2016) 27 exacerbate mining's effects on hydrology, ecosystems, and air quality (Phillips, 2016; Ali et al., 2018); 28 increase contamination risks (Metcalfe and Bui, 2016); and disrupt and slow mine site rehabilitation 29 (Wardell-Johnson et al., 2015; Hancock et al., 2017). Adaptations such as improved water management are 30 emerging slowly (Gasbarro et al., 2016; Becker et al., 2018). Some companies are spatially diversifying and 31 relocating (Hodgkinson et al., 2014). Others are replacing workers with automation and remote operations 32 (Halteh et al., 2018; Keenan et al., 2019). | 2093 - 209 | 'rot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | Impact Source Mass bleaching of the Great Barrier Reef in 2016/2017 due to a marine heatwave Box 11.2 In the New Zealand Southern Alps, extreme glacier mass loss was at least six times more likely in 2011, and ten times more likely in 2018, due to warming 11.2.1, 11.3.3 In the Australian Alps bioregion, loss of habitat for endemic and obligate species due to snow loss and increases in fire, drought and temperature Table 11.4 In the Australian wet tropics world heritage area, some vertebrate species have declined in distribution area and population size due to increasing temperatures and length of dry season Table 11.4 Extinction of Bramble Cay melomys due to loss of habitat caused by storm surges and sea�level rise in Torres Strait Table 11.4 In New Zealand, increasing invasive predation pressure on endemic forest birds surviving in cool forest refugia due to anthropogenic warming Table 11.4 In New Zealand, erosion of coastal habitats due to more severe storms and sea-level rise Table 11.4, Box 11.6 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 11 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 11-69 Total pages: 151 In Australia, estuaries warming and freshening with decreasing pH Table 11.6 Changes in life-history traits, behaviour or recruitment of fish and invertebrates due to ocean acidification or warming, severe decline in recruitment of coral on the Great Barrier Reef due to ocean warming, aquaculture stock deaths due to heat stress Table 11.6 New diseases and toxins due to warming and extension of East Australian Current Table 11.6 Changes in almost 200 marine species distributions and abundance due to ocean warming Table 11.6 Temperate marine species replaced by seaweeds, invertebrates, corals and fishes characteristic of subtropical and tropical waters Table 11.6 River flow decline in southern Australia is largely due to the decline in cool season rainfall partly attributed to anthropogenic climate change 11.3.3 In New Zealand, the 2007/08 drought and the 2012/13 drought were 20% attributed to anthropogenic climate change 11.3.3 In New Zealand, about 30% of the insured damage for the 12 costliest flood events from 2007-2017 can be attributed to anthropogenic climate change 11.3.8 In Australia, 35-36% of heat-related excess mortality in Melbourne, Sydney and Brisbane from 1991-2018 can be attributed to anthropogenic climate change 11.3.6 1 2 3 11.4 Indigenous Peoples 4 5 Indigenous perspectives of well-being embrace physical, social, emotional and cultural domains, 6 collectiveness and reciprocity, and more fundamentally connections between all elements across the past, 7 present and future generations (Australia. NAHS Working Party, 1989; MfE, 2020a). Changing climate 8 conditions are expected to exacerbate many of the social, economic and health inequalities faced by 9 Aboriginal and Torres Strait Islander Peoples in Australia and Māori in New Zealand (Bennett et al., 2014; 10 Hopkins et al., 2015; AIHW, 2016; Lyons et al., 2019) (high confidence). As a consequence, effective policy 11 responses are those that take advantage of the interlinkages and dependencies between mitigation, adaptation 12 and Indigenous Peoples' wellbeing (Jones, 2019) and those that address the transformative change needed 13 from colonial legacies (Hill et al., 2020) (high confidence). There is a central role for Indigenous Peoples in 14 climate change decision making that helps address the enduring legacy of colonisation through building 15 opportunities based on Indigenous governance regimes, cultural practices to care for land and water, and 16 intergenerational perspectives (Nursey-Bray et al., 2019; Petzold et al., 2020) (Cross-Chapter Box INDIG in 17 Chapter 18) (very high confidence). | 2095 - 209 | 'rot-Adapt-Mitig-Impa | INTANBILE | INDG |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 18 19 11.4.1 Aboriginal and Torres Strait Islander Peoples of Australia 20 21 The highly diverse Aboriginal and Torres Strait Islander Peoples of Australia have survived and adapted to 22 climate changes such as sea-level rise and extreme rainfall variability during the late Pleistocene era, through 23 intimate place-based Indigenous Knowledge in practice and while losing traditional land and sea Country 24 ownership (Liedloff et al., 2013) (Cross-Chapter-Box INDIG in Chapter 18) including during the Late 25 Pleistocene era (Golding and Campbell, 2009; Nunn and Reid, 2016). They belong to the world's oldest 26 living cultures, continually resident in their own ancestral lands, or 'country', for over 65,000 years 27 (Kingsley et al., 2013; Marmion et al., 2014; Nagle et al., 2017; Tobler et al., 2017; Nursey-Bray and 28 Palmer, 2018). The majority of the Australian Indigenous Peoples live in urban areas in southern and eastern 29 Australia, but are the predominant population in remote areas. | 2096 - 209 | Prot-Adapt-Mitig- | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 30 31 Climate-related impacts on Aboriginal and Torres Strait Islander Peoples, Countries (traditional estates) and 32 cultures have been observed across Australia and are pervasive, complex and compounding(Green et al., 33 2009) (11.5.1) (high confidence). For example, loss of bio-cultural diversity, nutritional changes through 34 availability of traditional foods and forced diet change, water security, and loss of land and cultural resources 35 through erosion and sea-level rise (Table 11.10) ](TSRA, 2018). Moreover, these impacts are being 36 experienced now particularly in low-lying geographical areas- especially in the Torres Strait Islands (Mosby, ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 11 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 11-70 Total pages: 151 1 2012; Kelly, 2014; Murphy, 2019; Hall et al., 2021). Estimates of the loss from fire impacts on ecosystem 2 services that contribute to the wellbeing of remotely-located Indigenous Australians were found to be higher 3 than the financial impacts from the same fires on pastoral and conservation lands (Sangha et al., 2020) and 4 could increase with both financial and non-financial impacts (Box 11.1). | 2096 - 209 | 'rot-Adapt-Mitig-Impa | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | IPAs can avoid the potential for 'nature–cultures dualism' that locks out Indigenous access in some protected area legislation, as they are based on relational values informed by local Indigenous Knowledge (Lee, 2016) Fire management using cultural practices can achieve greenhouse gas emission targets while also maintaining Indigenous cultural heritage. | 2098 - 209 | Prot-Adapt-Mitig- | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 14 15 Māori have long-term interests in land and water and are heavily invested in climate sensitive sectors 16 (agriculture, forestry, fishing, tourism and renewable energy) (King et al., 2010). Large proportions of 17 collectively owned land already suffer from high rates of erosion (Warmenhoven et al., 2014; Awatere et al., 18 2018) which are projected to be exacerbated by climate change induced extreme rainfalls (RSNZ, 2016; 19 Awatere et al., 2018) (high confidence). Changing drought occurrence, particularly across eastern and 20 northern New Zealand, is also projected to affect primary sector operations and production (King et al., 21 2010; Smith et al., 2017; Awatere et al., 2018) (medium confidence). Further, many Māori-owned lands and 22 cultural assets such as marae and urupa are located on coastal lowlands vulnerable to sea-level rise impacts 23 (Manning et al., 2014; Hardy et al., 2019) (high confidence). Māori tribal investment in fisheries and 24 aquaculture faces substantial risks from changes in ocean temperature and acidification, and the downstream 25 impacts for species distribution, productivity and yields (Law et al., 2016) (medium confidence). A clearer 26 understanding of climate change risks and the implications for sustainable outcomes can enable more 27 informed decisions by tribal organisations and governance groups. | 2099 - 209 | Impact | INTANBILE | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 11 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 11-73 Total pages: 151 1 2 3 Table 11.12: Climate-related impacts and risks for Tangata Whenua New Zealand Māori Impact Risks Changes in drought occurrence and extreme weather events Risks to Māori tribal investment in forestry, agriculture and horticulture sector operations and production, particularly across eastern and northern New Zealand (King et al., 2010; Awatere et al., 2018; Hardy et al., 2019)(medium confidence) Changes in rainfall, temperature, drought, extreme weather events and ongoing sea-level rise Risks to potable water supplies (availability and quality) for remote Māori populations (RSNZ, 2016; Henwood, 2019)(medium confidence) Changes in rainfall, temperature, drought, extreme weather events and ongoing sea-level rise Risks of exacerbating existing inequities (e.g. health, economic, education and social services), social cohesion and well-being (Bennett et al., 2014; Jones et al., 2014)(medium confidence) Changes in rainfall regimes and more intense drought combined with degradation of lands and water Risks to the distribution and survival of cultural keystone flora and fauna, as well as cascading risks for Māori customary practice, cultural identity and well-being (King et al., 2010; RSNZ, 2016; Bond et al., 2019)(high confidence) Changes in ocean temperature and acidification Risks to nearshore and ocean species productivity and distribution, as well as cascading risks for Māori tribal investment in the fisheries and aquaculture sectors (King et al., 2010; Law et al., 2016)(medium confidence) Sea-level rise induced erosion, flooding and saltwater intrusion Risks to Māori-owned coastal lands and economic investment as well as risks to community wellbeing from displacement of individuals, families and communities (Manning et al., 2014; Smith et al., 2017; Hardy et al., 2019)(high confidence) Sea-level rise induced erosion, inundation and saltwater intrusion Risks to Māori cultural heritage as well as cascading risks for tribal identity and spiritual well-being (King et al., 2010; Manning et al., 2014; RSNZ, 2016)(medium confidence) Impacts of climate change, adaptation and mitigation actions Risks that governments are unable to uphold Māori interests, values and practices under the Treaty of Waitangi, creating new, modern-day breaches of the Treaty of Waitangi (Iorns Magallanes, 2019; MfE, 2020a)(high confidence) 4 5 6 11.5 Cross-Sectoral and Cross-Regional Implications 7 8 The impacts and adaptation processes described in sections 11.3 and 11.4 are focused on specific sectors, 9 systems and Indigenous Peoples. Added complexity, risk and adaptation potential stem from cross-sectoral 10 and cross-regional inter-dependencies. | 2099 - 210 | Prot-Adapt-Mitig-Impac | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 52 53 The intangible costs of climate impacts - including death and injury, impacts on health and wellbeing, 54 education and employment, community connectedness, and the loss of ancestral lands, cultural sites and 55 ecosystems (Barnett et al., 2016; Warner et al., 2019) - affect multiple sectors and systems and exacerbate 56 existing vulnerabilities. While often incommensurable, intangible costs may be far higher than the tangible 57 costs. For example, following the Victorian fires in 2009, the tangible costs were A$3.1 billion while the ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 11 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 11-76 Total pages: 151 1 intangible costs were A$3.4 billion; following the Queensland floods in 2010/11, the tangible costs were 2 A$6.7 billion while the intangible costs were A$7.4 billion (Deloitte, 2016). | 2102 - 210 | Impact | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | For 0.5 m SLR, the value of buildings in New Zealand exposed to coastal inundation could increase by NZ$12.75 billion and the current 1-in-100 year flood in Australia could occur several times a year. For 1.0 m SLR, the value of exposed assets in New Zealand would be NZ$25.5 billion. For 1.1 m SLR, the value of exposed assets in Australia would be A$164- 226 billion. This would be associated with displacement of people, disruption and reduced social cohesion, degraded ecosystems, loss of cultural heritage and livelihoods, and loss of traditional lands and sacred sites. | 2107 - 2107 | | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | Exposure: Population growth, new and infill urbanization, tourism developments in low�lying coastal areas. Buildings, roads, railways, electricity and water infrastructure. Torres Strait Island and remote Māori communities are particularly exposed and sensitive. | 2107 - 2107 | | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII _Full_Report | 8. Cascading, compounding and Consequences: Widespread and pervasive damage and disruption to human activities generated by interdependencies and interconnectedness of physical, social and natural ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 11 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 11-82 Total pages: 151 aggregate impacts on cities, settlements, infrastructure, supply-chains and services due to extreme events (high confidence) (11.2, 11.3.4, 11.3.5, 11.3.6, 11.3.7, 11.3.8, 11.3.9, 11.3.10, 11.4, 11.5.1, Boxes 11.1, 11.4, 11.6) systems. Examples include: Failure of transport, energy and communication infrastructure and services, heat-stress, injuries and deaths, air pollution, stress on hospital services, damage to agriculture and tourism, insurance loss from heatwaves and fires; failure of transport, stormwater and flood-control infrastructure and services from floods and storms; water restrictions, reduced agricultural production, stress for rural communities, mental health issues, lack of potable water from droughts; damage to buildings, roads, railways, electricity and water infrastructure, loss of assets and lives, displacement of people, reduced social cohesion, and degraded ecosystems from extreme sea-level rise. Large aggregate costs due to lost productivity and major disaster relief expenditure, creating unfunded liabilities and supply chain disruption, e.g., the 2019-2020 Australian fires cost A$8 billion. | 2108 - 210 | Impact | INTANBILE | |
| IPCC_AR6_WGII _Full_Report | Exposure: Highly populated areas, rural and remote settlements, traditional lands and sacred sites. Greater urban density and population growth increases exposure in high-risk areas. Different exposure for different hazards, e.g. heatwaves: urban and peri-urban areas; fire: peri-urban areas and settlements near forests; floods: people, property and infrastructure from pluvial floods in cities and settlements and fluvial floods on floodplains; storms: buildings and infrastructure in cities and settlements. | 2109 - 210 | Impact | INTANBILE | |
| IPCC_AR6_WGII _Full_Report | 6 7 Some businesses have initiated active adaptation (Aldum et al., 2014; Linnenluecke et al., 2015; Bremer and 8 Linnenluecke, 2017; CCATWG, 2017; MfE, 2018) with most focused on identifying climate risks (Aldum et 9 al., 2014; Gasbarro et al., 2016; Cradock-Henry, 2017). Businesses are more likely to engage in anticipatory 10 adaptation when the frequency of climate events is known (McKnight and Linnenluecke, 2019). Effective 11 cooperation and a positive innovation culture can contribute to the collaborative development of climate 12 change adaptation pathways (Bardsley et al., 2018) (medium confidence). | 2114 - 211 | 'rot-Adapt-Mitig-Impa | | |

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| Report Title (Year) | Quotation Content | Page(s) | Prot-Adapt-Mitig-Impact* | Intangible** | Indigenous*** |
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| IPCC_AR6_WGII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 12 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 12-4 Total pages: 181 1 2 Changes in timing and magnitude of precipitation and extreme temperatures are impacting 3 agricultural production (high confidence). Since the mid-20th century, increasing mean precipitation has 4 positively impacted agricultural production in Southeast South America, although extremely long dry spells 5 have become more frequent affecting the economies of large cities in southeast Brazil. Inversely, reduced 6 precipitation and altered rainfall at the start and end of the rainy season and during the mid-summer drought 7 is impacting rainfed subsistence farming particularly in the Dry Corridor in Central America and in the 8 tropical Andes compromising food security (high confidence). The crop growth duration for maize for those 9 regions was reduced by at least 5% between 1981-2010 and 2015-2019. {12.3.1, 12.3.2, 12.3.6, Table 12.4} 10 11 Climate change affects the epidemiology of climate-sensitive infectious diseases in the region (high 12 confidence). Examples are the effects of warming temperatures on increasing the suitability of transmission 13 of vector-borne diseases, including endemic and emerging arboviral diseases such as dengue fever, 14 chikungunya, and Zika (medium confidence). The reproduction potential for the transmission of dengue 15 increased between 17% and 80% for the period 1950-54 to 2016-2021 depending on the subregion as a result 16 of changes in temperature and precipitation (high confidence). {12.3.1, 12.3.2, 12.3.3, 12.3.5, 12.3.6, Table 17 12.1} 18 19 The Andes, northeast Brazil and the northern countries in Central America are among the more 20 sensitive regions to climatic-related migrations and displacements, a phenomenon that has increased 21 since AR5 (high confidence). Climatic drivers interact with social, political, geopolitical and economical 22 drivers; the most common climatic drivers for migration and displacements are droughts, tropical storms and 23 hurricanes, heavy rains and floods (high confidence). {12.3.1.4, 12.3.2.4, 12.3.3.4, 12.3.5.4, 12.5.8.4} 24 25 The impacts of climate change are not of equal scope for men and women (high confidence). Women, 26 particularly the poorest, are more vulnerable and are impacted in greater proportion. Often they have less 27 capacity to adapt, further widening structural gender gaps (high confidence). {12.3.7.3, 12.5.2.4, 12.5.2.5, 28 12.5.7.3, 12.5.8.1, 12.5.8.3, 12.5.8.4} 29 30 Current adaptation responses: 31 32 Ecosystem-based adaptation is the most common adaptation strategy for terrestrial and freshwater 33 ecosystems (high confidence). There is a focus on the protection of native terrestrial vegetation through 34 implementation of protected areas and payment for ecosystem services, especially those related to water 35 provision. The adaptation measures in place, however, are insufficient to safeguard terrestrial and freshwater 36 ecosystems in the CSA from negative impacts of climate change (high confidence). {12.5.1, 12.5.3, 12.6} 37 38 Adaptation initiatives in ocean and coastal ecosystems mainly focus on conservation, protection and 39 restoration) (high confidence). The main adaptation measures are ocean zoning, the prohibition of 40 productive activities (e.g., fisheries, aquaculture, mining, tourism) on marine ecosystems, the improvement 41 of research and education programs, and the creation of specific national policies (high confidence). {12.5.2} 42 43 Adaptive water management has mainly centred on enhancing quantity and quality of water supply, 44 including large infrastructure projects, which, however, are often contested and can exacerbate water 45 related conflicts (high confidence). Inclusive water regimes that overcome social inequalities and 46 | 2181 - 218 | 'rot-Adapt-Mitig-Impa( | INTANBILE | INDG |

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| IPCC_AR6_WGII_Full_Report | 56 other drivers in perceived productivity changes. Index insurance builds resilience and contributes to ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 12 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 12-7 Total pages: 181 1 adaptation both by protecting farmers' assets in the face of major climate shocks, by promoting access to 2 credit, and by the adoption of improved farm technologies and practices. {12.5.4} 3 4 Institutional instability, fragmented services and poor water management, inadequate governance 5 structures, insufficient data and analysis of adaptation experience are barriers to address the water 6 challenges in the region (high confidence). {12.5.3} 7 8 Inequality, poverty and informality shaping cities in the region increase vulnerability to climate 9 change while policies, plans or interventions addressing these social challenges with inclusive 10 approaches are opportunities for adaptation (high confidence). Initiatives to improve informal and 11 precarious settlement, guaranteeing access to land and decent housing, are aligned with comprehensive 12 adaptation policies that include development and reduction of poverty, inequality and disaster risk (medium 13 confidence). {12.5.5, 12.5.7} 14 15 Adaptation policies often address climate impact drivers, but seldom include the social and economic 16 underpinnings of vulnerability. This narrow scope limits adaptation results and compromises their 17 continuity in the region (high confidence). In a context of unaddressed underdevelopment, adaptation 18 policies tackling poverty and inequality are marginal, underfunded, and not clearly included at national, 19 regional or urban levels. Dialogue and agreement including multiple actors are mechanisms to acknowledge 20 trade-offs and promote dynamic, site-specific adaptation options (medium confidence). {12.5.7} 21 22 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 12 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 12-8 Total pages: 181 1 12.1 Introduction 2 3 12.1.1 The Central and South America Region 4 5 Central and South America (CSA) is a highly diverse region, both culturally and biologically. It harbours one 6 of the highest biodiversity on the planet (Hoorn et al., 2010; Zador et al., 2015; IPBES, 2018a) (Cross- 7 Chapter Paper 1: Biodiversity Hotspots) and a wealth of cultural diversity resulting from more than 800 8 Indigenous Peoples who share the territory with European and African descendants and more recent Asian 9 migrants (CEPAL, 2014). Moreover, it is one of the most urbanized regions in the world, with some of the 10 most populated metropolitan areas (UNDESA, 2019). Several countries in the region have experienced 11 sustained economic growth in the last decades, making important advances in reducing poverty in the area. | 2184 - 218 | Prot-Adapt-Mitig-Impac | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 54 55 Observed changes in streamflow and water availability affect vulnerable regions (WGII AR5 Chapter 27, 56 Magrin et al., 2014). Glacier mass changes in the Andes over the past decades are among the most negative 57 ones worldwide (SROCC Chapter 2, Hock et al., 2019). This reduction has modified the frequency, ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 12 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 12-12 Total pages: 181 1 magnitude and location of related natural hazards, while the exposure of people and infrastructure has 2 increased because in relation with growing population, tourism and economic development (high confidence) 3 (SROCC Chapter 2, Hock et al., 2019). | 2189 - 2190 | | | |
| IPCC_AR6_WGII_Full_Report | 40 41 12.3.4 South America Monsoon (SAM) Sub-region 42 43 12.3.4.1 Hazards 44 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 12 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 12-24 Total pages: 181 1 Temperature extremes have likely increased in the intensity and frequency of hot extremes and decrease in 2 the intensity and frequency of cold extremes (Donat et al., 2013; Bitencourt et al., 2016) (WGI AR6 Table 3 11.13) (Seneviratne et al., 2021). In a vast transition zone between the Amazon and the Cerrado Biomes 4 within the region, analysis of seasonal precipitation trends suggested that almost 90% of the observational 5 sites showed reduced in the length of the rainy season in the region (Debortoli et al., 2015), on a period from 6 1971 to 2014 (Marengo et al., 2018), confirming the growth in length of the dry season. Changes in the 7 hydrological and precipitation regimes, characterized by reduction in rainfall in Southern Amazonia, 8 contrasting to an increase in the northwest Amazonia, and overall increases in extreme precipitation and in 9 the frequency of Consecutive Dry Days, is being reported by several authors (Fu et al., 2013; Almeida et al., 10 2017; Marengo et al., 2018; Espinoza et al., 2019a) with low confidence (WGI AR6 Table 11.14; 11 Seneviratne et al., 2021) due to insufficient data coverage and trends in available data generally not 12 significant. | 2201 - 2202 | | | |
| IPCC_AR6_WGII_Full_Report | 47 48 Studies with terrestrial animals show that habitat loss increases the vulnerability of species to climate change 49 (high confidence) (de Oliveira et al., 2012; Arnan et al., 2018; da Silva et al., 2018b). NES' coral reefs have 50 shown some resilience to bleaching, but vulnerability is intensified by the synergism between chronic heat 51 stress caused by increased sea surface temperature (Teixeira et al., 2019) and other well-documented 52 stressors, such as coastal runoff, urban development, marine tourism, overexploitation of reef organisms and 53 oil extraction (high confidence) (Figure 12.8; Leão et al., 2016). | 2207 - 2207 | | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII _Full_Report | 16 17 18 12.4 Key Impacts and Risks 19 20 This section synthesizes key risks across the Central and South America CSA region. It follows the 21 definition and concept of risk provided in AR5, distinguishing the risk components, climatic hazard, 22 exposure and vulnerability of people and assets (IPCC, 2014). This concept is further developed in AR6, 23 defining key risks as potentially severe risks (Section 16.5). Key risks may refer to present or future 24 conditions, with a focus on the 21st century. Both mitigation and adaptation can moderate the extent or 25 severity of risks. The identification and evaluation of risks imply socio-cultural values, which may vary 26 across individuals, communities or cultures. | 2222 - 222 | 'rot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII _Full_Report | 7. Risk to coral reef ecosystems due to coral bleaching ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 12 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 12-47 Total pages: 181 Degradation and possible death of the Mesoamerican coral reef, the second largest reef in the world. Severe damage to habitat for marine species, degrading coastal protection and other ecosystem services, decreased food security from fisheries, lack of income from tourism. | 2224 - 222 | 'rot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII _Full_Report | Continued exposure to increased atmospheric $CO_2$ levels and sea surface temperatures together with destruction from coastal development, fishing practices and tourism. | 2225 - 222 | Impact | | |
| IPCC_AR6_WGII _Full_Report | Increased number of people, infrastructure and services (coastal tourism) exposed; need of relocation of millions of people. | 2225 - 2225 | | | |
| IPCC_AR6_WGII _Full_Report | Poor planning in coastal development and infrastructure, disproportionate vulnerability and limited adaptation options for rural communities and Indigenous Peoples, increasing urbanisation in coastal cities. Large economic losses and unemployment from declining tourism. | 2225 - 222 | Prot-Adapt-Mitig- | | INDG |
| IPCC_AR6_WGII _Full_Report | 12 13 Rural communities in the Cusco Region, Peru, ground their ability to adapt to climate change on four 14 cultural values, known in Quechua as ayni (reciprocity), ayllu (collectiveness), yanantin (equilibrium) and 15 chanincha (solidarity), but policies oriented towards “modernization” undermine these traditional 16 mechanisms. Adaptation strategies could benefit from integrating these and other insights from traditional 17 cultures, fostering risk reduction and transformational adaptation towards intrinsically sustainable systems 18 (medium confidence: medium evidence, high agreement) (Walshe and Argumedo, 2016). | 2231 - 223 | 'rot-Adapt-Mitig-Impa | INTANBILE | |
| IPCC_AR6_WGII _Full_Report | 45 46 12.5.2 Ocean and Coastal Ecosystems and their Services 47 48 Ocean and coastal ecosystems provide suitable habitats to a high number of species that support important 49 local fisheries, the tourism sector and the economy of the region (high confidence) (Section 3.5; Table 3.9; 50 González and Holtmann-Ahumada, 2017; Venerus and Cedrola, 2017; CEPAL, 2018; Carvache-Franco et 51 al., 2019; SROCC Section 5.4 Bindoff et al., 2019). There is high confidence that CSA ocean and coastal 52 ecosystems are already impacted by climate change (Figure 12.9, 12.10; Table SM12.3; Section 3.4; , 53 Section 5.4 in SROCC, Bindoff et al., 2019), and highly sensitive to non-climate stressors (Figure 12.8; 54 Table SM12.3; Section 3.4). Projections for CSA ocean and coastal ecosystems alert about significant and 55 negative impacts (high confidence) which include major loss of ecosystem structure and functionality, 56 changes in the distributional range of several species and ecosystems, major mortality rates, and increasing ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 12 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 12-54 Total pages: 181 1 number of coral bleaching events (Figure 12.9; Figure 12.10; Table SM12.3; Section 3.4; SROCC Sections 2 5.3, 5.4, Bindoff et al., 2019). | 2231 - 223 | Impact | | |
| IPCC_AR6_WGII _Full_Report | 3 4 12.5.2.2 Adaptation success in ocean and coastal ecosystems of CSA 5 6 There is low evidence about how the strategies and actions taken and implemented in ocean and coastal 7 systems of CSA have contributed to advance in the protection and conservation of ocean and coastal 8 ecosystems. However, some important advances are visible in Colombian Pacific areas with coral reefs (new 9 conservation plans, research monitoring and conservation practices) (low confidence) (Cruz-Garcia and 10 Peters, 2015; Alvarado et al., 2017; Bayraktarov et al., 2020). In Panama, actions taken have allowed the 11 protection of a high number of marine areas with coral reefs, as well as the incorporation of management 12 approaches that include several sectors such as fisheries, tourism, coral protection and coral conservation 13 (low confidence) (Alvarado et al., 2017). In the case of Costa Rica, 80% of coral habitats are located inside 14 of MPAs, multiple research coral-related activities have been performed, and several training activities have 15 favoured the engagement of the local community in their protection against climate and non-climate hazards 16 (low confidence) (Alvarado et al., 2017). | 2233 - 223 | Prot-Adapt-Mitig- | | |

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| IPCC_AR6_WGII_Full_Report | 17 18 There is low evidence of how the incorporation of mangroves as Ramsar sites, the reforms of legislations 19 (e.g., fines and stronger regulations), and the creation of reserves and private protection initiatives (e.g., 20 Belize Association of Private Protected Areas BAPPA), and capacity-building projects or new educational 21 programs have promoted the protection of mangroves in CSA countries such as Honduras, Guatemala and 22 Belize (Cvitanovic et al., 2014; Carter et al., 2015; Ellison et al., 2020). In Brazil, between 75–84% of 23 mangroves are under some level of protection which has improved the forest structures, and multiple 24 research programs (e.g., Mangrove Dynamics and Management, MADAM, and 'GEF-Mangle') have been 25 developed (medium confidence) (Krause, 2014; Medeiros et al., 2014; Estrada et al., 2015; Ferreira and 26 Lacerda, 2016; Oliveira-Filho et al., 2016; Borges et al., 2017; Maretti et al., 2019; Strassburg et al., 2019). | 2233 - 223 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | 12 13 Some important limits and barriers have been detected for productive systems such as fisheries and tourism 14 in CSA (medium confidence: medium evidence, high agreement). Brazilian major fisheries management do 15 not follow an ecosystem approach, although some small-scale fisheries apply a precautionary approach 16 (Singh-Renton and McIvor, 2015). The management of Peruvian artisanal (medium and small-scale 17 fisheries) are minimal with an important lack of regulations, control, and management actions (Bertrand et 18 al., 2018). In Argentina, marine recreational fisheries have been largely unregulated with a lack of 19 monitoring programs which have contributed to the overexploitation of some key coastal stocks (Venerus 20 and Cedrola, 2017). Moreover, the participation of women fishers in CSA is not equally considered being 21 excluded from the decision-making processes (FAO, 2016b; Bruguere and Williams, 2017). Due to the lack 22 of monitoring programs, it is unknown how this tourism industry will respond to long-term changes driven 23 by climate change (Weatherdon et al., 2016). | 2236 - 2236 | | | |
| IPCC_AR6_WGII_Full_Report | 8 9 12.5.3.2 Main concepts and approaches 10 11 Adaptation in the water sector includes a broad set of responses to improve and transform, among others, 12 water infrastructure, ecosystem functions, institutions, capacity building and knowledge production, habits 13 and culture, and local-national policies (Section 4.6). | 2238 - 223 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | 14 15 Most adaptive water management approaches in CSA centre around extending the water supply side 16 including large infrastructure projects. However, 'hard path' interventions are now strongly contested due to 17 negative effects exacerbating local water conflicts (Carey et al., 2012; Boelens et al., 2019; Drenkhan et al., 18 2019), potentially leading to increasing water demand, vulnerabilities and water shortage risks (Di 19 Baldassarre et al., 2018), and, hence, limiting adaptive capacity (high confidence) (Ochoa-Tocachi et al., 20 2019). More integrated approaches focus on multi-use of water storage with shared stakeholder vision, 21 responsibilities, rights and costs, as well as risks and benefits, and often integrating water and risk 22 management (Branche, 2017; Haeberli et al., 2017; Drenkhan et al., 2019). In this chapter, a feasibility 23 assessment was carried out for six major dimensions of multi-use water storage for the entire CSA (see Table 24 12.11). While geophysical and economic aspects allow for the implementation of water storage projects with 25 multi-use approach, the institutional, social and environmental dimensions pose a major barrier (see Section 26 12.5.3). Further demand-oriented approaches focus on incentives for the reduction of water use through 27 changes in people's habits, efficiency increase and smart water management (Gleick, 2002). These are 28 promoted in some regions, such as in CA and NWS (e.g., Colombia, Ecuador and Peru), to foster a 29 sustainable water culture (Bremer et al., 2016; Paerregaard et al., 2016). | 2238 - 223 | 'rot-Adapt-Mitig-Impa | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 3 4 Most barriers to advance adaptation in CSA correspond to soft limits associated with missing links of 5 science-society-policy processes, institutional fragilities, pronounced hierarchies, unequal power relations 6 and top-down water governance regimes (high confidence). One example is the abandonment of hydrological 7 long-term monitoring sites within tropical Andean ecosystems (paramo) in Venezuela (Rodríguez-Morales et 8 al., 2019) due to the lack of governmental support within a political crisis. In that regard, the collection and 9 availability of consistent hydroclimatic and socioeconomic data at adequate scales represent an important 10 challenge in CSA. Major adaptation barriers are furthermore reported from Central Chile in the context of a 11 mega-drought since 2010, related to socioeconomic characteristics and a deficient bottom-up approach to 12 public policy informing and development (Aldunce et al., 2017). These gaps could be bridged by 13 strengthening transdisciplinary approaches at the science-policy interface (Lillo-Ortega et al., 2019) with 14 blended bottom-up and top-down adaptation to include scientific knowledge with impact and scenario 15 assessments into local adaptation agendas (Huggel et al., 2015b). For instance, a new allocation rule for the 16 Laja reservoir in Southern Chile (SWS), based on consistent water balance modelling results, could inform 17 policy and water management and potentially improve local water management and reduce water conflicts 18 on the long term (Muñoz et al., 2019b). | 2241 - 224 | 'rot-Adapt-Mitig-Impa | | |

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| IPCC_AR6_WGII_Full_Report | 47 48 Limited information regarding cost-benefit analyses of adaptation is available in the region as well as 49 avoiding maladaptation effects and promoting site-specific and dynamic adaptation options considering 50 available technologies (medium confidence) (Roco et al., 2017; Zavaleta et al., 2018; Ponce, 2020; Shapiro- 51 Garza et al., 2020). | 2242 - 224 | 'rot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGII_Full_Report | Coffee, beans and maize Several adaptation practices Awareness of climate change Affordabilit y of adaptation practices Lack of adaptatio n involving agroecolo gical and socioeco nomic contexts Chen et al. (2018) Costa Rica and Nicaragua 559 Quant. Several crops Intensificatio n and diversificatio n Access to weather information Participation in organization s Credit access Farming experience Land renting Lack of crop and practices diversific ation Vidal Merino et al. (2019) Peru 137 Quant. Several crops Water management Farm size Capital Irrigated proportion Limited access to off-farm activities Small cultivated area Lack of site�specific design of interventi ons Meldrum et al. | 2245 - 224 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | 5 6 Housing programs and initiatives that consider resilient construction, and site selection strategies, are still in 7 nascent stages (Martin et al., 2013). Initiatives in slum upgrading, social housing improvement and 8 regularizing land tenure, associated with infrastructure provision, do not usually focus on adaptation, 9 although they often focus on risk reduction. Those initiatives, associated with a housing policy that 10 guarantees access to land and decent housing, a comprehensive intervention in vulnerable neighbourhoods 11 for their adaptation to climate change, and CbA (community-based adaptation) strategies, including housing 12 self-management and the participation of cooperatives, shows the need and opportunity to move to an 13 transformative urban agenda that encompasses sustainable development, poverty reduction, disaster-risk 14 reduction, climate-change adaptation, and climate-change mitigation (high confidence) (Muntó, 2018; UN- 15 Habitat, 2018; Valadares and Cunha, 2018; Bárcena et al., 2020b; Núñez Collado and Wang, 2020; 16 Satterthwaite et al., 2020). | 2249 - 224 | 'rot-Adapt-Mitig-Impac | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 17 18 Another example of a public adaptation measure is protection and restoration of natural areas, which have 19 the potential to decrease the transmission of water- and vector-borne infectious diseases (medium 20 confidence: robust evidence, low agreement). Studies have shown that these measures can diminish the cases 21 of malaria and diarrhoea in Brazil, and cases of diarrhoea in children in Colombia (Bauch et al., 2015; 22 Herrera et al., 2017; Chaves et al., 2018). However, deforestation and malaria have a complex relationship 23 that relies on local context interactions, where land use and land cover change present an important role due 24 to vector ecology alterations and social conditions of human settlements (Rubio-Palis et al., 2013). Forest 25 conservation can improve hydrological cycle control and soil erosion that can help to improve water quality 26 and reduce the burden of water-borne diseases. In addition, forest cover can help to diminish the habitat for 27 larval mosquitoes that transmit malaria. These measures can help to design policies in sites where these ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 12 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 12-77 Total pages: 181 1 problems do not currently exist but can emerge as a consequence of climate change and the increase in the 2 frequency of weather extreme events. | 2254 - 225 | Prot-Adapt-Mitig- | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 35 36 In IPCC's TAR, AR4 and AR5, WG II recognized higher risks associated with poor living conditions, 37 substandard housing, inadequate services, location in hazardous sites due to no alternatives and the need to 38 work more strongly on strengthening governance structures involving residents, community organizations 39 amongst others (Wilbanks et al., 2007; Revi et al., 2014). The AR5 CSA chapter stated that poverty levels 40 remained high (45% for CA and 30% for SA in 2010) despite years of sustained economic growth. Poor and 41 vulnerable groups are disproportionately affected in negative ways by climate change (Section 8.2.1.4; 42 Section 8.2.2.3; SR15 Section 5.2 and Section 5.2.1, Roy et al., 2018) ) due to physical exposure derived 43 from the place where they live or work, illiteracy, low income and skills, political and institutional 44 marginalization tied to lack of recognition of informal settlements and employments, poor access to good 45 quality services and infrastructure, resources, information, and other factors (very high confidence) (UN- 46 Habitat, 2018; SR15 Sections 5.2.1, 5.6.2, 5.6.3, 5.6.4, Roy et al., 2018). | 2256 - 225 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 37 38 There is also increasing evidence of human mobility associated with climate change and disaster risk (IOM, 39 2021) and the adoption of sustainable tourism, diversification of livelihoods strategies, climate forecasts, 40 appropriate construction techniques, neighbourhood layout, integral urban upgrading initiatives, territorial 41 and urban planning, regulatory frameworks, water harvesting and nature-based solutions (NbS) (Stein and 42 Moser, 2014; Hardoy and Mastrangelo, 2016; Almeida et al., 2018; Barbier and Hochard, 2018a; Desmaison 43 et al., 2018; Satterthwaite et al., 2018; Villafuerte et al., 2018; Hidalgo, 2020; Satterthwaite et al., 2020). | 2259 - 225 | Impact | | |

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| IPCC_AR6_WGII_Full_Report | 34 Indigenous and social movements have joined with climate justice activists, claiming for action against 35 climate change (Hicks and Fabricant, 2016; Ruiz-Mallén et al., 2017; Charles, 2021). The Bolivian Platform 36 against Climate Change, a coalition of civil society and social movement organizations working to address 37 the effects of global warming in Bolivia and to influence the broader global community, reflects an 38 innovative dimension that, albeit at time conflictual, has flagged how increasing climate variability hinders 39 the right of Indigenous Peoples to the conservation of their culture and practices and illustrates how grass- 40 root movements are increasingly appropriating climate change policy in the region (Hicks and Fabricant, 41 2016). Social movements have engaged with international networks as Blokadia, which surged after COP 23, 42 whose vindications try to go beyond the protection of the environment, delving into issues of democracy and 43 resource control (Martínez-Alier et al., 2018). | 2261 - 226 | 'rot-Adapt-Mitig-Impa( | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 10 11 Mean air temperature and annual rainfall (measured through instruments since 1891 and inferred through 12 historical records of rogation ceremonies since 1600), are increasing, combined with an increase in 13 seasonality (i.e., longer periods of drought) and extreme weather events, particularly stronger precipitations 14 (Serrano Vincenti et al., 2017; Domínguez-Castro et al., 2018). Two impacts related to warmer air conditions 15 are the displacement of the freezing line currently placed at 5100 m.a.s.l. (Basantes-Serrano et al., 2016), 16 followed by glacier retreat and the upward displacement of mountainous ecosystems (very high confidence) 17 (Vuille et al., 2018; Cuesta et al., 2019). The key ecosystem that regulates water provision for the city is the 18 paramo, and only about 5% of this process is related with glaciers, so the combined effects of climate change 19 on both systems, coupled with land use change and fires, can reduce the availability of water for agriculture, 20 human consumption and hydropower. Other important climatic hazards and impacts are the increase of solar 21 radiation, the heat island effect and fires (high confidence) (Anderson et al., 2011; Armenteras et al., 2020; 22 Ranasinghe et al., 2021). Almost half of the days of each year, Quito's population is exposed to levels of UV 23 radiation above 11 according to the World Health Organization scale (Municipio del Distrito Metropolitano 24 de Quito, 2016). | 2272 - 227 | Impact | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 25 26 Various policies, programs and projects have been created for the promotion of urban green spaces, 27 protected areas, water sources and watersheds monitoring, conservation and ecosystem restoration, air 28 pollution monitoring and control, and urban agriculture. Among those actions, three recent are commonly 29 highlighted. The first is the Fund for the Protection of Water (FONAG), established in 2000 with funds of 30 national and international organizations, to promote the protection of the water basins that supply most of the 31 drinking water. It is a PES-Scheme (Payment for Ecosystem Services) enabled through a public-private 32 escrow. The projects include conservation, ecological restoration, and environmental education for a new 33 culture of water, in a context opposed to the commodification of natural resources (Kauffman, 2014; Bremer 34 et al., 2016; Coronel T, 2019). FONAG was innovative in the use of trust funds in a voluntary, decentralized 35 mechanism and has inspired more than 21 other water funds in the region; nevertheless, its narrative of 36 success has also been said to over-simplify and misrepresent some complex interactions between 37 stakeholders as well as within communities and their land management practices (Joslin, 2019). | 2272 - 227 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | 19 20 The institutionalized culture of participation in Peru did lead to a broader concept of concertation, wherein 21 practices of collaborative planning were developed to allow actors to build up socially supported agreements, 22 decisions and take actions without losing sight of their principles. These processes have been applied to 23 reduce risks, to adapt and to anticipate uncertain and unknown futures; and introducing climate change 24 concerns within a complex political and institutional environment surrounded by corruption scandals 25 (Vergara, 2018; Durand, 2019) and growing political polarization. | 2275 - 227 | 'rot-Adapt-Mitig-Impa( | INTANBILE | |

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| IPCC_AR6_WGII_Full_Report | 19 20 12.7.1 Knowledge Gaps in the Subregions 21 22 The knowledge gaps in the eight subregions are quite heterogeneous. In CA, climate change research is 23 notably insufficient in all sectors included in this report, considering that climatic change, variability, and 24 extremes are and will severely impact this subregion, and the vulnerability of the social and natural systems 25 is high. Data deficiencies must be overcome as renewed research on climate change updates models, 26 scenarios, and projected impacts across sectors and levels (i.e., household to country). In NWS, there is a 27 lack of studies on the relationships with increased fire events, and the impacts on the infrastructure of all 28 kinds, on certain lowland, marine and coastal ecosystems, and on ecosystem functioning and the provision of 29 environmental services. Experimental studies are rare, most necessary to identify critical ecological 30 thresholds to support the decision-making processes, linking glacier retreat to its consequences on 31 biodiversity and ecosystems, combined with different land-use trajectories. Complex interactions with 32 processes such as peace agreements in Colombia are yet to be studied (Salazar et al., 2018). In NSA, there is 33 still a limited amount of peer-reviewed literature, addressing the implications of climate change on 34 Indigenous cultures and their livelihoods. In SAM, further data are needed on the vulnerability of traditional 35 populations, impacts on water availability and soil degradation, risks to biodiversity and resilience of 36 ecosystems, attributed to climate change. | 2277 - 227 | Impact | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 40 41 12.7.2.4 Food, Fibre and other Ecosystem Products 42 43 Integrative evaluation on impacts on food security, including agricultural production, distribution and access, 44 leading to adaptation strategies is limited within the region. Limited information regarding cost-benefit 45 analyses of adaptation in the food production sector is available in the region. It is also important to advance 46 in a better understanding of the adaptation effects to avoid maladaptation and promote site-specific and 47 dynamic adaptation options considering available technologies. Compiling and systematizing existing 48 scientific and local knowledge on the relationship between forest, land cover/use, and hydrological services, 49 is a gap to be filled, in a broader perspective in the region, that can contribute to provide recommendations 50 and inform restoration practices and policies. The literature also highlights widespread gaps between 51 farmers' information needs and services that are routinely available. There is evidence that when Climate 52 Information Services are constructed with farmer input and are targeted in a timely and inclusive manner, 53 they are a positive determinant of adaptation through the adoption of more resilient farm level practices. | 2278 - 227 | 'rot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGII_Full_Report | 32 33 12.7.2.8 Cross Cutting Issues it the Human Dimension 34 35 There is a significant number of studies addressing the impacts of climate change on the Amazon forest 36 (Brienen et al., 2015; Doughty et al., 2015; Feldpausch et al., 2016; Rammig, 2020; Sullivan et al., 2020); 37 however, the assessment of tangible and intangible impacts of climate change on Indigenous Peoples 38 cultures and livelihoods in this forest, need to be further advanced (Brondízio et al., 2016; Hoegh-Guldberg 39 et al., 2018). | 2280 - 228 | Impact | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 15 16 17 12.8 Conclusion 18 19 Central and South America (CSA) is a broadly heterogeneous region in its topography, ecosystems, urban 20 and rural territories, demography, economy, cultures and climates. The region relies on a strong agrarian 21 economy in which small producers and large industries participate, but also large industrialized urban 22 centres, oil production and mining. The region is one of the most urbanized of the world and home to many 23 Indigenous Peoples, some still in isolation, and exhibits one of the highest rates of inequality, which is a 24 structural and growing characteristic in CSA. Poverty and extreme poverty rates are higher among children, 25 young people, women, Indigenous Peoples, migrant and rural populations but urban extreme poverty is also 26 growing (very high confidence). Socioeconomic challenges are intensified by COVID crisis. Most countries 27 in CA are already ranked as the highest risk level worldwide due to its exposure combined to high 28 vulnerability and low adaptive capacity; the lack of climate data and proper downscaling are challenging the 29 adaptation process (high confidence). | 2281 - 228 | 'rot-Adapt-Mitig-Impac | | INDG |
| IPCC_AR6_WGII_Full_Report | 4 5 Many impacts in the economy are expected from climate change. Subsistence farmers and urban poor are 6 expected to be the most impacted by droughts and variable rainfall in the region (high confidence). The 7 increasing water scarcity is and will continue to impact food security, human health and well-being. The 8 impacts of the many landslides and floods affect mainly the urban poor neighbourhoods and are responsible 9 for the majority of the deaths related to natural disasters. Sea-level rise and intense storm surges are expected 10 to impact the tourism and industry in general. Internal and international migrations and displacements are 11 expected to increase (high confidence). Climatic drivers such as droughts, tropical storms and hurricanes, 12 heavy rains and floods, interact with social, political, geopolitical and economical drivers (high confidence). | 2282 - 228 | Impact | INTANBILE | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 43 This process degraded the ability of coastal ecosystems, such as mangroves, to reduce risks and provide 44 essential ecosystem services which help to prevent coastal erosion or maintain fish stocks. Moreover, it 45 reduced ports, tourism, along with income opportunities. | 2285 - 228 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 29 Glacier retreat and water scarcity are becoming strong drivers of migration in the Andes. Sea level rise 30 influences activities such as fishing and tourism, which will foster further migration. In Brazil, at least 0.9 31 million more people will migrate inter–regionally under future climate conditions. | 2287 - 2287 | | | |
| IPCC_AR6_WGII_Full_Report | 34 35 The wide range of adaptation practices based on Indigenous knowledge in the region include, among others: 36 increasing species and genetic diversity in agricultural systems through community seed exchanges; 37 promotion of highly diverse crop systems; ancient systems to collect and conserve water; fire prevention 38 strategies; observing and monitoring changes in communal ecological–agricultural calendar cycles; 39 recognizing changes in ecological indicators like migration patterns in birds, behaviour of insects and other 40 invertebrates and phenology of fruit and flowering species; and systematization and knowledge exchange 41 among communities. These practices represent a valuable cultural and biological heritage. | 2289 - 228 | Prot-Adapt-Mitig- | | INDG |
| IPCC_AR6_WGII_Full_Report | 49 50 Traditional fire management among Indigenous Peoples of Venezuela, Brazil and Guyana is another 51 adaptation strategy based on a fine–tuned understanding of environmental indicators, associated with their 52 culture and worldviews. In these countries, Indigenous lands have the lowest incidence of wildfires, 53 significantly contributing to maintaining and enhancing biodiversity. These traditional practices have helped 54 to prevent large–scale and destructive wildfires, reducing the risk from rising temperature and dryness due to 55 climate change. | 2289 - 228 | 'rot-Adapt-Mitig-Impac | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 35 36 KR4: Due to warming, changes in precipitation and sea level rise, risks to people and infrastructures 37 from coastal, riverine, and pluvial flooding will increase in Europe (high confidence). Risks of 38 inundation and extreme flooding will increase with accelerating pace of sea level rise along Europe's coasts 39 (high confidence). Above 3°C GWL, damage costs and people affected by precipitation and river flooding may double. Coastal flood damage is projected to increase at least 10-fold by the end of the 21st 40 century, and 41 even more or earlier with current adaptation and mitigation (high confidence). Sea level rise represents an 42 existential threat for coastal communities and their cultural heritage, particularly beyond 2100 43 {13.2.1;13.2.2;13.6.2;13.10.2.4;Box 13.1; Cross-Chapter Box SLR in Chapter 3). | 2363 - 236 | 'rot-Adapt-Mitig-Impact | | |
| IPCC_AR6_WGII_Full_Report | 49 50 Systemic barriers constrain the implementation of adaptation options in vulnerable sectors, regions 51 and societal groups (high confidence). Key barriers are limited resources, lack of private sector and citizens 52 engagement, insufficient mobilisation of finance, lack of political leadership, and low sense of urgency. Most 53 of the adaptation options to the key risks depend on limited water and land resources, creating competition 54 and trade-offs, also with mitigation options and socio-economic developments (high confidence). Europe 55 will face difficult decisions balancing these trade-offs. Novel adaptation options are pilot tested across 56 Europe, but upscaling remains challenging. Prioritisation of options and transitions from incremental to ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 13 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 13-6 Total pages: 143 1 transformational adaptation are limited due to vested interests, economic lock-ins, institutional path- 2 dependencies, and prevalent practices, cultures, norms, and belief systems {13.11.1;13.11.2;13.11.3}. | 2364 - 236 | 'rot-Adapt-Mitig-Impac | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 36 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 13 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 13-9 Total pages: 143 1 2 13.1.3 Impact Assessment of Climate Change based on Previous Reports 3 4 The main findings of previous reports, particularly the WGII AR5 (Kovats et al., 2014) and the Special 5 Report of Global warming of 1.5°C GWL (Hoegh-Guldberg et al., 2018), highlighted the impacts of 6 warming and rainfall variations and their extremes on Europe, particularly southern Europe and mountainous 7 areas. At 2°C GWL, 9% of Europe's population was projected to be exposed to aggravated water scarcity, 8 and 8% of the territory of Europe were characterized to have a high or very high sensitivity to desertification 9 (UNEP/UNECE, 2016). These impacts are driven by changes in temperature, precipitation, irrigation 10 developments, population growth, agricultural policies, and markets (EEA, 2017a). Heat is a main hazard for 11 high-latitude ecosystems (Kovats et al., 2014; Jacob et al., 2018; Hock et al., 2019). The majority of 12 mountain glaciers lost mass during the last two decades, and permafrost in the European Alps and 13 Scandinavia is reducing (Hock et al., 2019). In central Europe, Scandinavia and Caucasus, mountain glaciers 14 were projected to lose 60% to 80% of their mass by the end of the 21st century (Hock et al., 2019). The 15 combined impacts on tourism, agriculture, forestry, energy, health and infrastructure were suggested to make 16 southern Europe highly vulnerable and increase the risks of failures and vulnerability for urban areas (Kovats 17 et al., 2014). Previous reports stated that the adaptive capacity in Europe is high compared to other regions of 18 the world, but that there are also limits to adaptation from physical, social, economic, and technological 19 factors. Evidence suggested that staying within 1.5°C GWL would strongly increase Europe's ability to 20 adapt to climate change (de Conick and Revi, 2018). | 2367 - 236 | 'rot-Adapt-Mitig-Impa | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 12 13 14 13.2 Water 15 16 13.2.1 Observed Impacts and Projected Risks 17 18 13.2.1.1 Risk of Coastal Flooding and Erosion 19 20 Almost 50 million European citizens live within 10 m above mean sea level (Vousdoukas et al., 2020; 21 McEvoy et al., 2021). Without further adaptation (section 13.2.2), flood risks along Europe's low-lying 22 coasts and estuaries will increase due to sea level rise (SLR) compounded by storm surges, rainfall and river 23 runoff (high confidence) (Mokrech et al., 2015; Arns et al., 2017; Sayol and Marcos, 2018; Vousdoukas et 24 al., 2018a; Bevacqua et al., 2019; Couasnon et al., 2020). The population at risk of a 100-year flood event 25 starts to rapidly increases beyond 2040 (Vousdoukas et al., 2018a) reaching 10 million people under RCP8.5 26 by 2100 but stays just below the 10 million under RCP2.6 by 2150 (Figure 13.5, Haasnoot et al., 2021b) 27 assuming present population and protection. The number of people at risk is projected to increase and risk to 28 materialise earlier particularly under SSP5 due to increasing population trends(Vousdoukas et al., 2018a; 29 Haasnoot et al., 2021b). Under high rates of SLR resulting from rapid ice-sheet loss from Antarctica, risks 30 may increase by a third by 2150 (Haasnoot et al., 2021b). Expected annual (direct) damages due to coastal 31 flooding are projected to rise from €1.3 billion today to €13–39 billion by 2050 between 2°C and 2.5°C 32 GWL and €93–960 billion by 2100 between 2.5° and 4.4°C GWL, largely depending on socio-economic 33 developments (Cross-Chapter Box SLR in Chapter 3, Vousdoukas et al., 2018a) (high confidence in the sign; 34 low confidence in the numbers). UNESCO World Heritage sites in the coastal zone are at risk due to SLR, 35 coastal erosion and flooding (CCP4, Section 13.8.1.3, Marzeion and Levermann, 2014; Reimann et al., 36 2018b) as are coastal landfills and other key infrastructure in Europe (AR6/SROCC, Brand et al., 2018; 37 Beaven et al., 2020). | 2371 - 237 | 'rot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | 47 48 49 [START BOX 13.1 HERE] 50 51 Box 13.1: Venice and its Lagoon 52 53 Venice and its lagoon are a UNESCO World Heritage Site. This socio-ecological system is the result of 54 millennia of interactions between people and the natural environment. It is exposed to climatic and non- 55 climatic hazards: more frequent floods, warming, pollution, invasive species, reduction of salt marshes, 56 hydrodynamic and bathymetric changes, and waves generated by cruise ships and boat traffic. | 2371 - 2371 | | | |
| IPCC_AR6_WGII_Full_Report | 9 Construction of the flood protection system started in 2003 and were used for the first time in October 2020 10 to protect the city from floods (Lionello et al., 2021b). This system of mobile barriers (MoSE) closes the 11 lagoon inlets to avoid floods when needed, while under normal conditions they lay on the seabed, thus 12 allowing ship traffic and the exchange between the lagoon and the sea (Molinaroli et al., 2019). To prevent 13 the flooding of the central monument area, additional measures are proposed including inlets, expansion of 14 saltmarshes, and pumping seawater into deep brackish aquifers to raise the city's level (Umgiesser, 1999; 15 Umgiesser, 2004; Teatini et al., 2011). | 2372 - 237 | Prot-Adapt-Mitig- | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 15 Peatlands in NEU and EEU and other historically important cultural landscapes in Europe are overexploited 16 for forestry, agriculture, and peat mining (Page and Baird, 2016; Tanneberger et al., 2017; Ojanen and 17 Minkkinen, 2020). Inland wetland RAMSAR convention sites in Europe, which constitute 47% of the global 18 sites, have lost area in WCE and gained in SEU from 1980 to 2014 (Xi et al., 2021). Forests in WCE were 19 impacted by the extreme heat and drought event of 2018, with effects lasting into 2019 (Schuldt et al., 2020) 20 and losses in conifer timber sales in Europe (Hlásny et al., 2021). | 2380 - 238 | Impact | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 16 17 18 Disruption of habitat connectivity reduces resilience and is projected to impact 30% of lake and river 19 catchments in Europe by 2030, through drought and reduced river flows (Markovic et al., 2017) (medium 20 evidence). Average wetland area is not projected to change at 1.7°C GWL across Europe, while for > 4°C 21 GWL expanding sites in NEU are not sufficient to balance losses in SEU and WCE (high confidence) (Xi et 22 al., 2021). At 3°C GWL the alpine tundra habitat and its associated species are projected to be lost in the 23 Pyrenees and shrink dramatically in NEU, WCE and EEU (Anisimov et al., 2017; Barredo et al., 2020). | 2382 - 238 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 30 31 13.3.2 Solution Space and Adaptation Options 32 33 Autonomous species adaptation, via range shifts towards higher latitudes and altitudes and changes in 34 phenology, but extirpation have been documented in all European regions (Figure 13.8) (very high 35 confidence). Lowering vulnerability by reducing other anthropogenic impacts (Gillingham et al., 2015), such 36 as land use change, habitat fragmentation (Eigenbrod et al., 2015; Oliver et al., 2017; Wessely et al., 2017), 37 pollution, and deforestation (Chapter 2), enhances adaptation capacity and biodiversity conservation (high 38 confidence) (Ockendon et al., 2018). Protected areas, such as the EU Natura 2000 network, have contributed 39 to biodiversity protection (medium confidence) (Gaüzère et al., 2016; Sanderson et al., 2016; Santini et al., 40 2016; Hermoso et al., 2018) but 60% of terrestrial species in these sites could lose suitable climate niches at 41 4°C GWL (Figure Box 13.1.1, EEA, 2017a). | 2385 - 238 | 'rot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | 27 28 The solution space for responding to climate-change risks for terrestrial ecosystem has increased in parts of 29 Europe (medium confidence). For example, EbA and NbS figure prominently in the EU Adaptation Strategy 30 (2021a) and climate change adaptation is mainstreamed in the EU Biodiversity Strategy for 2030 (European 31 Comission, 2020), the EU Forest Strategy for 2030 (European Comission, 2021b), the EU Green 32 Infrastructure Strategy (European Comission, 2013a), as well as several national and regional policies. Yet, 33 in the northern parts of EEU and NEU (e.g. Greenland, Iceland, NW Russian Arctic), areas which are often 34 sites of pronounced biodiversity shifts and changes, solutions are lacking or slow in emergence, due to 35 remoteness, lack of resources and sparse populations (Canosa et al., 2020). In the EU, innovative financing 36 schemes such as the Natural Capital Financing Facility are being explored by the European Investment Bank 37 and the European Commission which supports projects delivering on biodiversity and climate adaptation 38 through tailored loans and investments. Multiple EU-level service platforms have been promoted to track 39 climate change impacts on land ecosystems and adaptation (e.g. Climate-Adapt, Copernicus Land and Fire 40 Monitoring Service, Forest Information System of Europe) (13.11.1). | 2386 - 238 | 'rot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | 44 45 'Green' adaptations, either 'Ecosystem based Adaptations' or 'Nature based Solutions, are part of adaptive 46 management strategies (European Comission, 2011) that facilitate coastal flood protection (Section 13.2.2; 47 Chapter 3; CCC SLR) and generate benefits beyond habitat creation (medium confidence), e.g., from avoided 48 expenditures for flood defence infrastructure and avoided loss of the built assets (Gedan et al., 2010). Marine 49 Protected Areas (MPAs) have been identified as adaptation options for natural areas, including permitted and 50 non-permitted uses (Chapter 3, Selig et al., 2014; Hopkins et al., 2016a; Roberts et al., 2017). The extent of 51 MPAs has been increasing in Europe, albeit with strong regional variations (Figure 13.12). MPAs provide 52 protection from local stressors, such as commercial exploitation, and enhance the resilience of marine and 53 coastal ecosystems and thus lessen the impacts of climate change (medium confidence) (Narayan et al., 2016; 54 Roberts et al., 2017). However, climate change risk reduction is only a limited MPA objective (Hopkins et 55 al., 2016b; Rilov et al., 2019). The implementation of the legal frameworks, such as the EC Habitats 56 Directive and EC Birds Directive, allows for enabling adaptation (Verschuuren, 2015) as does the 57 incorporation of climate considerations in management of Natura 2000 sites (European Comission, 2013b). | 2390 - 239 | 'rot-Adapt-Mitig-Impa | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 35 36 37 13.6 Cities, Settlements and Key Infrastructure 38 39 Urban areas in Europe offer home to 547 million inhabitants, corresponding to 74% of the total European 40 population (UN/DESA, 2018). In the EU-28, 39% of the total population lives in metropolitan regions (i.e., 41 areas with at least one million inhabitants) where 47% of the total GDP is generated (Eurostat, 2016). Apart 42 from urban settlements, this section also covers energy and transport systems, as well as tourism, industrial 43 and business sectors which are key for livelihood, economic prosperity and well-being of residents. | 2400 - 2400 | | | |
| IPCC_AR6_WGII_Full_Report | 22 23 13.6.1.4 Tourism 24 25 Snow cover duration and snow depth in the Alps decreased since the 1960s (Klein et al., 2016; Schöner et 26 al., 2019; Matiu et al., 2021). Despite snowmaking, the number of skiers to French resorts at low elevations 27 during the extraordinary warm/dry winters of 2006/2007 and 2010/2011 was 12-26% lower (Falk and Vanat, 28 2016). | 2403 - 2403 | | | |
| IPCC_AR6_WGII_Full_Report | 29 30 Due to reduced snow availability and hotter summers, damages are projected for the European tourism 31 industry, with larger losses in SEU (high confidence) and some smaller gains in the rest of Europe (medium 32 confidence) (Ciscar et al., 2014; Roson and Sartori, 2016; Dellink et al., 2019). | 2403 - 240 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 43 44 Climatic conditions from May to October at 1.5-2°C GWL are projected to become more favourable for 45 summer tourism in NEU and parts of WCE and EEU, while there is medium confidence on opposite trends 46 for SEU from June to August (Grillakis et al., 2016; Scott et al., 2016; Jacob et al., 2018; Koutroulis et al., 47 2018). The amenity of European beaches may decrease as a result of sea level rise amplifying coastal erosion 48 and inundation risks, although less in NEU (Ebert et al., 2016; Toimil et al., 2018; Lopez-Doriga et al., 2019) 49 (Section 13.2 and Ranasinghe et al., 2021 Section 12.4.5). | 2403 - 240 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 36 37 38 Table 13.1: Present status of planned and implemented adaptation in cities, energy sector, tourism sector, transport and 39 industry in Europe ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 13 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 13-48 Total pages: 143 General commitments / Adaptation Plans Implemented adaptation actions Cities ● Increasing number of cities acknowledging the critical role of adaptation in building resilience to climate change. | 2406 - 240 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII Full Report | Tourism ● Consideration of tourism in national adaptation strategies is limited, and national tourism strategies rarely mention adaptation. | 2407 - 240 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII Full Report | ● Tourism operators do not consider longer term adaptation strategies to be relevant. | 2407 - 240 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII Full Report | ● Legally binding consideration of climate change when constructing new tourism units (e.g., the 2016 French Mountain Act). | 2407 - 2407 | | | |
| IPCC_AR6_WGII Full Report | ● Some diversification of tourism products offered in Mediterranean coastal destinations. | 2407 - 2407 | | | |
| IPCC_AR6_WGII_Full_Report | 39 Effectiveness & feasibility of main adaptation options to climate impacts & risk for cities, settlements & key infrastructure in Europe Impact types Adaptation options Effectiveness Economic Technological Institutional Socio-cultural Ecological Geophysical Evidence Agreement Interventions in the building shell M M L M L NL M M M Ventilation (natural/mechanical, incl. night) M M H M L NL M H M Air conditioning H L NL NL L NL M L M Shading M L H L M NL L M M Green roofs, green walls L M M L M M M M M Urban green spaces L L M L M M M L M Use of 'cool' paints & coatings L H M L M NL H M M Escape to nearby non-urban destinations NL NL NL NL M NL NL L H Improvements in cooling systems M L M M NL NL M H M Shifting production to less water�intensive plants M M M L NL NL NL L H Regulatory measures L M NL M NL NL NL L M Management measures M M M M NL L M M M Use of heat-resilient materials L H L M M NL NL L H Replace vulnerable infrastructure with resilient one L M NL NL NL NL NL L H Legend █ High = H █ Medium = M █ Low = L No/Limited Evidence = NL Feasibility Confidence Reduction of thermal comfort due to increasing temperatures & extreme heat Loss of critical services due to heatwaves & drought<br>ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 13 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 13-51 Total pages: 143 1 2 3 Figure 13.21: Indicative adaptation limits in cities, settlements and key infrastructure in Europe (Table SM13.16). | 2409 - 241 | Prot-Adapt-Mitig-Impac | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 53 54 There is limited knowledge on interactions created by synchronous adaptation in ski tourism supply and 55 demand, and models are not yet including individual snowmaking capacity and a higher time resolution 56 (Steiger et al., 2019). Furthermore, there is no European-wide assessment of coastal flooding risks on 57 tourism. | 2411 - 241 | Prot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGII_Full_Report | 23 24 25 The effectiveness of most options in reducing climate induced health risks is determined by many co- 26 founding factors, including the extent of the risk, existing socio-political structure and culture, and other 27 adaptation options in place (high agreement, medium evidence). Successful examples include the 28 implementation of heat wave plans (Schifano et al., 2012; van Loenhout and Guha-Sapir, 2016; De'Donato et 29 al., 2018), improvements in health services, and infrastructure of homes (Vandentorren et al., 2006) (Section 30 13.10.2.1). A study of nine European cities, for example, showed lower numbers of heat-related deaths in 31 Southern European cities, and attributed this to the implementation of heat prevention plans, a greater level 32 of individual and household adaptation, and growing awareness of citizens about exposure to heat 33 (de'Donato et al., 2015). Long-term national prevention programs in Northern Europe have been shown to 34 reduce temperature-related suicide (Helama et al., 2013). Physical fitness of individuals may increase 35 resilience to extreme heat (Schuster et al., 2017). Combining multiple types of adaptation options into a 36 consistent policy portfolio may have an amplifying effect in reducing risks, particularly at higher GWL 37 (Lesnikowski et al., 2019) (medium confidence) (Chapter 7). | 2417 - 241 | Prot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGII_Full_Report | 52 53 54 13.8 Vulnerable Livelihoods and Social Inequality 55 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 13 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 13-60 Total pages: 143 1 This section addresses social consequences of climate change for Europe, by looking into consequences for 2 poor households and minority groups; migration and displacement of people; livelihoods particularly 3 vulnerable to climate change (indigenous and traditional communities); and cultural heritage. | 2418 - 2419 | | | INDG |
| IPCC_AR6_WGII_Full_Report | 7 8 13.8.1.3 Loss and Damage to Vulnerable Livelihoods in Europe 9 10 A number of livelihoods maintaining unique cultures in Europe is particularly vulnerable to climate change 11 (Table 13.2): indigenous communities in the European polar region because of their dependence on 12 cryosphere ecosystems (high confidence) (CCP Polar, Hayashi, 2017; Huntington et al., 2017; Hock et al., 13 2019; Meredith et al., 2019; Inuit Circumpolar Council, 2020; Douville et al., 2021; Fox-Kemper et al., 14 2021) and communities dependent on small-scale fisheries, traditional farming and unique cultural 15 landscapes (medium confidence) (Kovats et al., 2014; Ruiz-Díaz et al., 2020). | 2420 - 242 | Impact | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 16 17 For Sámi reindeer herding impacts cascade due to a lack of access to key ecosystems, lakes and rivers 18 thereby threatening traditional livelihoods, food security, cultural heritage (e.g. burial grounds, seasonal 19 dwellings and routes), mental health (Box 13.2 and Figure 13.13, Feodoroff, 2021), and growing costs for 20 example as a result of the need for artificial feeding of reindeer. | 2420 - 242 | Impact | | |
| IPCC_AR6_WGII_Full_Report | Human life Communal and production sites and intrinsic value Sense of place Agency and identity Cultural artefacts Psychological and emotional distress Biodiversity and ecosystems 25 Climate hazard Change in exposure and vulnerability Observed impact / projected risk Loss of livelihood, culture, health and wellbeing of the Sámi and the Nenets. | 2420 - 242 | Impact | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | Loss of livelihood (e.g. reindeer herding), loss of food security (cold dependent species), culture, health (impact on safety; psychological impacts from stress to reindeer and Indigenous way of life), and cultural and linguistic wellbeing; release of anthrax from permafrost soils in the Nenets area. | 2420 - 242 | Impact | INTANBILE | INDG |
| IPCC_AR6_WGII Full Report | Warmer winters lead to loss of income from ice fishing and cultural heritage in Finland. | 2421 - 2421 | | | |
| IPCC_AR6_WGII Full Report | Abandonment of summer pastures and farms, with negative consequences for farming income, tourism, cultural and aesthetic values. | 2421 - 2421 | | INTANBILE | |

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| IPCC_AR6_WGII_Full_Report | Reduced yields on semi-natural grasslands, compromising livestock feeding in winter, and ultimately decreasing viability of pastoralism in the Spanish Pyrenees Higher temperatures and more variable precipitation, less snow, change in seasonality and drought Demographic change, change in policy and market conditions, simplification of pastoral practices and agroecosystems, land abandonment or afforestation of marginal pastoral lands and intensification of more favourable lands in the lowlands, troublesome coexistence with tourism and nature conservation initiatives Decreasing viability of pastoralism, concentration of pastoral production on most profitable locations for intensive rearing of livestock with abandonment of the rest of the land; pastoral land encroachment both by shrubs and other activities; grassland degradation; biodiversity loss Retreating glaciers and changes in the landscape lead to loss of identity, culture and self-reliance in the Italian Alps (Alto Adige) ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 13 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 13-63 Total pages: 143 1 2 3 [START BOX 13.2 HERE] 4 5 Box 13.2: Sámi Reindeer Herding in Sweden 6 7 Reindeer (Rangifer tarandus) are keystone species in northern landscapes (Vors and Boyce, 2009). Reindeer 8 herding is a traditional, semi-nomadic livelihood of the Sámi. Reindeer migrate between seasonal pastures 9 that cover 55% of Sweden and are simultaneously used for multiple other purposes (Sandström et al., 2016). | 2421 - 242 | Prot-Adapt-Mitig- | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 17 18 The documented and projected impacts on reindeer are complex and varied. Warming and CO2 increase 19 result in higher plant productivity (Section 13.3), changes in plant community composition, and higher 20 parasite harassment; unstable ice conditions affect migration; extreme weather conditions during critical 21 winter months, more frequent forest fires and changes in plant community composition reduce pasture 22 quality (medium confidence) (Mallory and Boyce, 2018) (Figure Box 13.2.1). High snow depth and rain-on�Glacier volume loss from increasing temperatures Vulnerability is mainly driven by reliance on tourism Loss of sense of community through shared memories, and history. Sadness caused by the loss of what feels like "home". Loss of well-being due to uncertainty and fear of the future. | 2422 - 242 | Impact | | |
| IPCC_AR6_WGII_Full_Report | Critical importance of alpine natural forests and meadows for regulating services; Negative impacts of climate change are found mainly at low elevations and for specific species (Norway spruce); decrease in soil moisture due to abandonment of pastoralism result in reduced water provision for downstream water users Increase of sea temperature leads to shifts in distribution of cold water species, reducing productivity at lower latitudes. Artisanal fisheries in Southern European coastal areas (Mediterranean) that rely on local, nearshore stocks can have difficulties to adapt Increase in sea temperature Substitution of artisanal fisheries by industrial fisheries; less support by governments, shift in employment (e.g. tourism) which do not match the skill sets, education or desires of small-scale fishers; national quotas system leads to prices to high buy or lease quotas and immense amount of bureaucracy and regulations Due to their low investment capacity and boat size, fishers are limited in their movement to other fishing places when local fish stocks decline. Increasing sea temperatures are increasing the threat of invasive species in coastal ecosystems. | 2422 - 242 | 'rot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGII_Full_Report | 22 23 Maintaining and improving the solution space to adapt reindeer herding is crucial for reducing existing 24 impacts and projected risks of climate and land use change (Andersson et al., 2015; Turunen et al., 2016; 25 AMAP, 2017; Hausner et al., 2020). Lack of control over land use is the biggest and most urgent threat to the 26 adaptive capacity of reindeer herding and the right of Sámi to their culture (high confidence) (Pape and 27 Löffler, 2012; Andersson et al., 2015; Kløcker Larsen and Raitio, 2019). | 2424 - 242 | 'rot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGII_Full_Report | 28 29 [END BOX 13.2 HERE] 30 31 32 13.8.1.4 Cultural and Natural Heritage 33 34 Climate change poses a serious threat to preservation of cultural heritage in Europe, both tangible and 35 intangible (high confidence) (Haugen and Mattsson, 2011; Daire et al., 2012; Dupont and Van Eetvelde, 36 2013; Macalister, 2015; Phillips, 2015; Fatorić and Seekamp, 2017; Graham et al., 2017; Carroll and 37 Aarrevaara, 2018; Sesana et al., 2018; Iosub et al., 2019; Daly et al., 2020). At higher GWL, building 38 exteriors and valuable indoor collections become at risk (Leissner et al., 2015). Coastal heritage such along 39 the North Sea and Mediterranean are under water-related threats (Reimann et al., 2018b; Walsh, 2018; 40 Harkin et al., 2020) (Box 13.1 Venice; WGII AR6 CCP4). | 2424 - 242 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 41 42 Disappearing cultural heritage can reduce incomes due to loss of tourism (Hall et al., 2016), as exemplified 43 by glacier retreat e.g. in the Swiss Alps and Greenland (Bjorst and Ren, 2015; Bosson et al., 2019) 44 (CCP5.3.2.4). Glacier retreat can create a sense of discomfort, loss of sense of place, displacement and 45 anxiety in people (Section 13.7) (Albrecht et al., 2007; Brugger et al., 2013; Allison, 2015; Jurt et al., 2015). | 2424 - 242 | Impact | INTANBILE | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 46 Intangible cultural heritage, such as place names, and lost traditional practices can also be affected 47 (Mustonen, 2018; Dastgerdi et al., 2019). | 2424 - 2424 | | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 15 16 European cultural heritage in general and world heritage sites specifically lack adaptation strategies to 17 preserve key cultural assets (Haugen and Mattsson, 2011; Howard, 2013; Heathcote et al., 2017; Reimann et 18 al., 2018b; Harkin et al., 2020). Key reasons are the underdeveloped adaptation actions available, resources 19 for implementing them, and absence of overarching policy guidance (Phillips, 2015; Fernandes et al., 2017; 20 Sesana et al., 2018; Daly et al., 2020) (Sesana et al., 2018; Fatorić and Biesbroek, 2020; Sesana et al., 2020). | 2425 - 242 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | 21 22 13.8.3 Knowledge Gaps 23 24 There is limited understanding of how different social groups are affected by the four European key risks 25 under future climate change (13.11.2), and by adaptation to them. Similarly, the interaction of multiple risks 26 across sectors and how this interaction results in displacement, migration, or immobility of people both 27 within and from outside Europe is insufficiently understood. For indigenous and traditional livelihoods in 28 Europe, the understanding of how risks will change at different warming levels is very limited, due to 29 complex interactions with socio-economic and political change. For European cultural heritage, there is also 30 a lack of tailored knowledge and understanding of the impacts and how to translate these into adaptation 31 measures. | 2425 - 242 | 'rot-Adapt-Mitig-Impact | | INDG |
| IPCC_AR6_WGII_Full_Report | 6 7 8 13.10.2.4 KR4: Risks to people, economies and infrastructures due to coastal and inland flooding 9 10 Damages and losses from coastal and river floods are projected to increase substantially in Europe over the 11 21st century (high confidence) (Section 13.2.1, SM13.10). Coastal areas have already started to be affected 12 by sea level rise (Box13.1; Section 13.10.1) and human exposure to coastal hazards is projected to increase 13 in the next decades (high confidence), but less under SSP1 (20%) than SSP5 (50%) by the end of the century 14 (medium confidence) (Merkens et al., 2016; Reimann et al., 2018a). Under low adaptation (i.e. coastal 15 defences are maintained but not further strengthened), severe consequences include increase in expected 16 annual damage by a factor of at least 20 for 1.5-2.1°C GWL (i.e.. high risks) and by 2-3 orders of magnitude 17 between 2 and 3°C GWL in EU-28 (i.e. very high risk) (medium confidence) (Figure 13.28, 13.34c; Section 18 13.2.1.1); (Vousdoukas et al., 2018b; Haasnoot et al., 2021b). Under high adaptation (i.e. lowlands are 19 protected where it is economically efficient), expected annual damages still increase by a factor of 5 above 20 2°C GWL (Section13.2, Vousdoukas et al., 2020). Sea-levels are committed to rise for (Fox-Kemper et al., 21 2021), submerging at least 10% of the territory in 12 countries in Europe after millennia if GWL exceed 1.5- 22 2.5°C (Clark et al., 2016), and this represents a major threat for the European and Mediterranean cultural 23 heritage (Figure 13.28, Cross-Chapter Box SLR in Chapter 3, CCP4, Marzeion and Levermann, 2014; 24 Reimann et al., 2018b). | 2434 - 243 | 'rot-Adapt-Mitig-Impact | | |
| IPCC_AR6_WGII_Full_Report | 3 There is also some evidence of 'short-sighted' adaptation or maladaptation; for example, in winter tourism 4 there is a preference for technical and reactive solutions (e.g., artificial snow) that will not be sufficient under 5 high levels of warming (Section 13.6.1.4). | 2442 - 244 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | 43 44 As warming and droughts impact southern Europe most strongly, direct opportunities from climate change 45 are primarily in northern regions, thereby increasing existing inequalities across Europe. Across Europe, 46 positive effects of climate change are fewer than negative impacts and are typically limited to some aspects 47 of agriculture, forestry, tourism, and energy sectors. In the food sector, opportunities emerge by the 48 northward movement of food production zones, increases in plant growth due to CO2 fertilisation, and 49 reduction of heating costs for livestock during cold winters. In the energy sector, positive effects include 50 increased wind energy in the southwestern Mediterranean, and reduced energy demand for heating across 51 Europe. While climatic conditions for tourist activities are projected to decrease for winter tourism (e.g. | 2449 - 244 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 52 lacking sufficient snow) and summer tourism in some parts of Europe (e.g. too hot), conditions may improve 53 during spring and autumn in many European locations. Fewer cold waves will reduce risks on transport 54 infrastructure, such as cracking of road surface, in parts of Northern and Eastern Europe particularly by the 55 end of the century. | 2449 - 244 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 14 Bellis, J., M. Longden, J. Styles and S. Dalrymple, 2021: Using macroecological species distribution models to estimate 15 changes in the suitability of sites for threatened species reintroduction. Ecological Solutions and Evidence, 2(1), 16 e12050, doi:https://doi.org/10.1002/2688-8319.12050. | 2454 - 2454 | | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 14 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 14-4 Total pages: 157 1 Indigenous Peoples across North America (high confidence). Climate change has impacted aquaculture (high 2 confidence) and induced rapid redistribution of species (very high confidence), and population declines of 3 multiple key fisheries (high confidence). {14.5.4, 14.5.6, 14.7} 4 5 Climate change has impaired North American freshwater resources and reduced supply security (high 6 confidence). Reduced snowpack and earlier runoff (high confidence) have adversely affected aquatic 7 ecosystems and freshwater availability for human uses (medium confidence). Recent severe droughts, floods 8 and harmful algal and pathogen events have caused harm to large populations and key economic sectors 9 (high confidence). Heavy exploitation of limited water supplies, especially in the western US and northern 10 Mexico, and deteriorating freshwater management infrastructure, have heightened the risks (high 11 confidence). Effective examples of freshwater resource adaptation planning are already underway, but 12 coordinated adaptation implementation across multiple conflicting interests and users is complicated and 13 time consuming (high confidence). {14.5.1, 14.5.2, 14.5.3} 14 15 Extreme events and climate hazards are adversely affecting economic activities across North America 16 and have disrupted supply-chain infrastructure and trade (high confidence). Larger losses and 17 adaptation costs are observed for sectors with high climate exposures, including tourism, fisheries, and 18 agriculture (high confidence) and outdoor labor (medium confidence). Disaster planning and spending, 19 insurance, markets, and individual and household level adaptation have acted to moderate effects to 20 date (medium confidence). Entrenched socioeconomic vulnerabilities have amplified climate impacts for 21 marginalized groups, including Indigenous Peoples due to the impact of colonialism and discrimination 22 (medium confidence). {14.5.4, 14.5.5, 14.5.6, 14.5.7, 14.5.9, Box 14.1, Box 14.5, Box 14.6} 23 24 North American cities and settlements have been affected by increasing severity and frequency of 25 climate hazards and extreme events (high confidence), which has contributed to, infrastructure 26 damage, livelihood losses, damage to heritage resources, and safety concerns. Impacts are particularly 27 apparent for Indigenous Peoples for whom culture, identity, commerce, health and wellbeing are closely 28 connected to a resilient environment (very high confidence). Higher temperatures have been associated with 29 violent and property crime in the US (medium confidence) yet the overall effects of climate change on crime 30 and violence in North America are not well understood. {14.4, 14.5.5, 14.5.6, 14.5.8, 14.5.9, Box 14.1} 31 32 Terrestrial, marine, and freshwater ecosystems are being profoundly altered by climate change across 33 North America (very high confidence). Rising air, water, ocean and ground temperatures have restructured 34 ecosystems and contributed to the redistribution (very high confidence) and mortality (high confidence) of 35 fish, bird, and mammal species. Extreme heat and precipitation trends on land have increased vegetation 36 stress and mortality, reduced soil quality, and altered ecosystem processes including carbon and freshwater 37 cycling (very high confidence). Warm and dry conditions associated with climate change have led to tree die-38 offs (high confidence) and increased prevalence of catastrophic wildfire (medium confidence) with an 39 increase in the size of severely burned areas in western North America (medium confidence). Nature-based 40 solutions and ecosystem-based management have been effective | 2505 - 250 | Prot-Adapt-Mitig-Impac | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 8 9 10 14.3.3 Building Consensus on Climate Change 11 12 Building consensus for action on climate change is influenced by individual factors (e.g., ideology, 13 worldview, trust, partisan identity, religion, education, age) and the broader societal context (e.g., culture, 14 media coverage and content, political climate, economic conditions) (high confidence) (McCright and 15 Dunlap, 2011; Brulle et al., 2012; Hornsey et al., 2016; Arbuckle, 2017; Pearson et al., 2017; Bolsen and 16 Shapiro, 2018; Ballew et al., 2020; Cologna and Siegrist, 2020; Goldberg et al., 2020). In a multi-country 17 assessment of acceptance of global warming influenced by ideology (e.g., conspiratorial ideation, 18 individualism, hierarchy, and left–right and liberal–conservative political orientation), the US uniquely had 19 the strongest link to doubt out of 25 countries for all factors, while Canada's dominant influence on non- 20 acceptance was conservative political ideology, and for Mexico, there were no ideological effects (Hornsey 21 et al., 2018). | 2518 - 251 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 31 Interest in preserving local archaeological sites threatened by SLR initiated collaboration and co-production 32 of knowledge among disparate US communities -- citizens, archaeologists, preservationists, planners, land 33 managers, and Indigenous Peoples (Fatorić and Seekamp, 2019; Dawson et al., 2020). | 2519 - 2519 | | | INDG |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 52 53 54 [START BOX 14.1 HERE] 55 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 14 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 14-18 Total pages: 157 1 Box 14.1: Integrating Indigenous 'Responsibility-Based Thinking' into Climate Change Adaptation 2 and Mitigation Strategies 3 4 Indigenous Peoples throughout North America have experienced five centuries of territorial expropriation, 5 loss of access to natural resources and in many cases, barriers to the use of their sacred sites (Gabbert, 2004; 6 Louis, 2007). The history of Indigenous struggles to preserve distinct cultural knowledges and assert 7 autonomy in the face of colonialism has shaped land-use patterns and relationships with traditional territories 8 (Alfred and Corntassel, 2005; Tuhiwai Smith, 2021) (Cross-Chapter Box INDIG, Chapter 18). Climate 9 change is now creating additional challenges for Indigenous Peoples. For example, increased water scarcity 10 due to higher temperatures and diminished precipitation have led to reduced crop yields for Maya farmers in 11 the Yucatan (Sioui, 2019). Thawing permafrost in subarctic Canada (Quinton et al., 2019) has interfered with 12 the land-based livelihoods of the Indigenous Dene Peoples (CCP6). | 2519 - 252 | Prot-Adapt-Mitig- | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 41 42 Indigenous relationships with natural systems continue to be mediated by cultural orders of governance and 43 legal systems that pre-date, by several millennia, European traditions in North America. Napolean (2012) 44 describes Indigenous legal orders as dynamic and encompassing knowledge that is simultaneously legal, 45 religious, philosophical, social, and scientific. Customary Indigenous legal orders (e.g. Borrows, 2002; 46 Napolean, 2012) stand in contrast to Eurocentric understandings of law, which are closely related to, and 47 founded on, the Western principles of rights. Indigenous legal orders are based on duties, obligations and 48 responsibilities to the land and all beings, including humans, animals, plants, future generations and the 49 departed/ancestors (Borrows, 2002; Borrows, 2010a; Borrows, 2010b; Borrows, 2016). Indigenous spiritual 50 laws centred on the values of responsibility and accountability to the land, and how these differ, in theory 51 and in practice, from Western law, which is based on "universal" principles, with little consideration for the 52 local environmental context (Craft, 2014). Research has elucidated these Indigenous understandings about 53 how their land-based responsibilities act as the foundation of how humans must operate according to the land 54 on which they live and depend. | 2520 - 2520 | | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 55 56 With increasing climate change threats to land-based subsistence and cultural practices, Indigenous Peoples 57 are increasingly taking their rightful leadership roles in resource co-management arrangements and other ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 14 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 14-19 Total pages: 157 1 stewardship activities (14.5.2.2). Indeed, Indigenous Peoples are increasingly assuming leadership positions 2 with regard to land governance and climate change action, as the stewards of their traditional territories since 3 time immemorial. Therefore, it is imperative for Indigenous scholars, Elders, and knowledge holders to 4 occupy leadership roles in climate change adaptation and mitigation, especially when their territories are 5 concerned (14.7; CCP6). For instance, Indigenous "resurgence" paradigms draw on the strengths of 6 traditional land-based culture and knowledge with regard to Indigenous leadership in land governance and 7 stewardship (Alfred and Corntassel, 2005; Alfred, 2009; Simpson, 2011; Corntassel and Bryce, 2012; 8 Coulthard, 2014; Alfred, 2015). Indigenous leadership in climate change policy, therefore, can ensure that 9 Indigenous right to self-determination is respected and upheld to allow Indigenous Peoples to continue to 10 carry out their cultural responsibilities to the land, for the benefit of all North Americans (Powless, 2012; 11 Etchart, 2017). | 2520 - 252 | Prot-Adapt-Mitig- | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 33 34 Responsibility-based philosophies of Indigenous Peoples from across the continent support the development 35 of climate change adaptation and mitigation strategies that promote responsible and respectful relationships 36 with the environment over the long term. Adapting to change, in all its forms, has since time immemorial 37 been one of the defining characteristics of Indigenous cultures on Turtle Island (the American continent). In 38 the Yucatan, one Elder explained that with regards to climate change impacts in the region, the Maya have 39 always dealt with "k'ech", or change, and that accepting and responding to change is part of the Maya 40 identity and responsibility (Sioui, 2020). Given successive failures in adequately and effectively responding 41 to climate change, it has become urgent for the rest of the human collective to (re)learn from Indigenous 42 cultures to (re)consider our responsibility/ies to the land—the world over—and to reorient our societal 43 imperatives to better respond and react to change. Such a process of learning from IK could foster the 44 development of climate change policies that promote responsible and respectful relationships with the 45 environment over the long term, and prove to be more effective and holistic. Although most inhabitants of 46 North America are non-Indigenous, it is possible and beneficial for our societies to learn to think and act in a 47 more responsibility-based way about our relations to the land, and, by extension, about climate change 48 policy. A collective commitment to protecting and advancing Indigenous territorial rights, so Indigenous 49 Peoples can continue to reassert their spiritual duty and role as stewards of their traditional territories, 50 benefits of all human and other-than-human 'Peoples'. | 2521 - 252 | 'rot-Adapt-Mitig-Impac | INTANBILE | INDG |

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| IPCC_AR6_WGII_Full_Report | 51 52 [END BOX 14.1 HERE] 53 54 55 14.4 Indigenous Peoples and Climate Change 56 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 14 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 14-20 Total pages: 157 1 Indigenous knowledge and science are resources for understanding climate change impacts and 2 adaptive strategies (very high confidence) (SM14.1, Table SM14.1). The Indigenous Peoples of North 3 America have and continue to contribute substantially to the growing literature, scholarship, and research on 4 climate change (Barreiro, 1999; Houser et al., 2001; Mustonen, 2005; Bennett et al., 2014; Maynard, 2014; 5 Merculieff et al., 2017; FAQI, 2019; Ijaz, 2019; BIA, 2021). For thousands of years, Indigenous Peoples 6 have developed and relied on their own knowledge systems for sustaining their health, cultures and arts, 7 livelihoods, and political security (Battiste and Henderson, 2000; Colombi, 2012; Nelson and Shilling, 8 2018). Diverse Indigenous knowledge systems in North America consider weather and climate as major 9 dimensions of understanding the relationship between society and the environment. Indigenous Peoples have 10 distinct knowledge of climate change, over extensive temporal measures (Trosper, 2002; Barrera-Bassols 11 and Toledo, 2005; Gearheard et al., 2013). The basis of this knowledge is often Indigenous Peoples' long 12 and profound relationships to the environment, that is to the ecosystems, waters, ice, lands, territories, and 13 resources in their homelands. The relationships were forged by adaptation to a particular environment and 14 involve systematic activities. Indigenous harvesters, including hunters, fishers, agriculturalists, and plant 15 gatherers, observe and monitor environmental change, and engage in systematic reflection with one another 16 about trends over short term and long-term periods (Sakakibara, 2010; Sánchez-Cortés and Chavero, 2011; 17 Kermoal and Altamirano-Jiménez, 2016; Metcalfe et al., 2020b). The holistic perspective of the interrelated 18 and interdependent nature of ecosystems is a distinct characteristic of Indigenous knowledge and often 19 contrasts with findings and results of science alone. Indigenous harvesters, agriculturalists, leaders, culture- 20 bearers, educators, and government employees develop theoretical and practical knowledge of seasonal and 21 climate change that seeks to furnish the best available knowledge and information to inform climate change 22 policy and decisions (Barrera-Bassols and Toledo, 2005; McNeeley and Shulski, 2011). Examples of 23 theoretical knowledge systems include Indigenous calendars of seasonal change and systems of laws and 24 protocols for environmental stewardship (Kootenai Culture Committee, 2015; Donatuto et al., 2020) (Box 25 14.1). | 2521 - 252 | 'rot-Adapt-Mitig-Impac | | INDG |
| IPCC_AR6_WGII_Full_Report | 26 27 The practice and use of Indigenous knowledge systems is recognized and affirmed by the United Nations 28 Declaration on the Rights of Indigenous Peoples (UNDRIP) (UNGA, 2007), and consistent with reports and 29 guidance from UN bodies including the High Commissioner for Human Rights (Bachelet, 2019), Expert 30 Mechanism on the Rights of Indigenous Peoples (UNGA, 2015; UNGA, 2018), the Permanent Forum of 31 Indigenous Issues (Dodson, 2007; Cunningham Kain et al., 2013; Sena and UNPFII, 2013; Sena, 2014; 32 Quispe and UNPFII, 2015), and the Special Rapporteur on the Rights of Indigenous Peoples (Toledo, 2013; 33 UNGA, 2017)(Cross-Chapter Box INDIG in Chapter 18). Rights to self-determination, to control over 34 territorial development, and cultural integrity, make it important that climate scientists practice equitable 35 engagement of Indigenous knowledge and Indigenous knowledge holders. There is a growing literature of 36 success and lessons learned from co-production of knowledge between Indigenous knowledge systems and 37 diverse scientific traditions relating to climate change (Behe et al., 2018; Latulippe and Klenk, 2020; 38 Camacho-Villa et al., 2021). | 2522 - 2522 | | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 46 Indigenous persons are more at risk of losing their lives due to factors that are exacerbated by climate change 47 impacts (Ford et al., 2006; Barbaras, 2014; Khalafzai et al., 2019). Indigenous Peoples' livelihood practices 48 are being distressed, interrupted, and in some cases, made entirely inaccessible. Livelihood activities known 49 and anticipated to be impacted by climate change are food security (Meakin and Kurtvits, 2009; Wesche and 50 Chan, 2010; Nyland et al., 2017), harvesting of fish, plants, and wildlife (Dittmer, 2013; Parlee et al., 2014; 51 Jantarasami et al., 2018b; ICC Alaska, 2020), agriculture (St. Regis Mohawk Tribe, 2013; Shinbrot et al., 52 2019; Settee, 2020), transportation (Swinomish Indian Tribe Community, 2010; Hori et al., 2018a; Hori et 53 al., 2018b), and tourism and recreation (ICC Canada, 2008). Indigenous Peoples have been active in 54 gathering to assess the impacts of climate change on their livelihoods, one example being the Bering Sea 55 Elders Advisory Group (Bering Sea Elders Advisory Group and Alaska Marine Conservation Council, 2011; 56 Bering Sea Elders Group, 2016). | 2522 - 252 | 'rot-Adapt-Mitig-Impac | | INDG |

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| Report Title (Year) | Quotation Content | Page(s) | Prot-Adapt-Mitig-Impact* | Intangible** | Indigenous*** |
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| IPCC_AR6_WGII_Full_Report | 57 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 14 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 14-21 Total pages: 157 1 Climate change impacts have harmful effects on Indigenous Peoples' public health, physical health, 2 and mental health, including harmful effects connected to the cultural and community foundations of 3 health (very high confidence). Health and climate change is a major issue for Indigenous Peoples (Ford, 4 2012; Ford et al., 2014; Gamble et al., 2016; Jantarasami et al., 2018b; Middleton et al., 2020a; Donatuto et 5 al., 2021)(14.5.6). Climate change impacts and risks affect Indigenous Peoples' health negatively in different 6 ways. Indigenous health, as tied to nutrition and exercise, is threatened when local foods are less available 7 and harvesting activities are less possible to practice (Norton-Smith et al., 2016b; Rosol et al., 2016; 8 Gonzalez et al., 2018). Indigenous Peoples experience widespread public health concerns from severe 9 droughts (Stewart et al., 2020; Schlinger et al., 2021; Wiecks et al., 2021), extreme heat (Doyle et al., 2013; 10 Campo Caap, 2018; Kloesel et al., 2018a; Meadow et al., 2018; ITK, 2019; Ute Mountain Ute Tribe and 11 Wood Environment Infrastructure Solutions Inc, 2019; Whyte et al., 2021), unpredictable precipitation 12 patterns (Chavarria and Gutzler, 2018; Tom et al., 2018; Tlingit and Haida, 2019; Schlinger et al., 2021), 13 flooding and coastal erosion (Jamestown S'klallam Tribe, 2016; Norton-Smith et al., 2016b; Puyallup Tribe 14 of Indians, 2016; Marks-Marino, 2019; Ristroph, 2019; Marks-Marino, 2020b; Schlinger et al., 2021), 15 wildfires and wildfire smoke (Edwin and Mölders, 2018; USEPA, 2018; Christianson et al., 2019a; ITK, 16 2019; Marks-Marino, 2020a; Mottershead et al., 2020; Woo et al., 2020; Wiecks et al., 2021), algal blooms 17 (Peacock et al., 2018; Gobler, 2020; Donatuto et al., 2021; Preece et al., 2021; Schlinger et al., 2021), storms 18 and hurricanes (Rioja-Rodríguez et al., 2018), influxes of invasive species (Pfeiffer and Huerta Ortiz, 2007; 19 Pfeiffer and Voeks, 2008; Voggesser et al., 2013; Bad River Band of Lake Superior Tribe of Chippewa 20 Indians and Abt Associates Inc., 2016; Scott et al., 2017; Reo and Ogden, 2018; Middleton et al., 2020a), 21 and changing production systems (Rioja-Rodríguez et al., 2018). Indigenous Peoples' mental health is at risk 22 and has already been affected negatively by climate change (Donatuto et al., 2021). Water security is one of 23 the most serious concerns to Indigenous Peoples' health and wellbeing (Vanderslice, 2011; Cozzetto et al., 24 2013a; Redsteer et al., 2013; Hanrahan et al., 2014; Chief et al., 2016; Gamble et al., 2016; Jantarasami et 25 al., 2018b; Kloesel et al., 2018a; Tom et al., 2018; Martin et al., 2020a; Arsenault, 2021). When some people 26 are less able to practice traditional, cultural, social, and family activities, they can become alienated, 27 compounding the negative effects of traumas Indigenous persons already experience. Traumas include 28 historic and continuing land dispossession, assimilation, social marginalization and discrimination, and food 29 and financial insecurities. The practice of cultural traditions are associated with education, harvesting and 30 agriculture, exercise, positive social relationships, and family life, which play foundational roles in the 31 achievement of physical, public, and mental health (Bell et al., 2010; Cunsolo Willox et al., 2015; 32 Jantarasami et al., 2018b; Norgaard and Tripp, 2019; Billiot et al., 2020b; Adams et al., 2021; Donatuto et 33 al., 2021). | 2522 - 252 | Impact | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 33 34 Impacts on Human Systems 35 36 Increased fire activity, partly attributable to anthropogenic climate change, has had direct and indirect effects 37 on mortality and morbidity, economic losses and costs, key infrastructure, cultural resources, and water 38 resources (medium confidence), although other factors, such as increasing populations in the wildland-urban 39 interface, also contributed. During 2000–2018, significant fire events claimed 315 lives in the US (NOAA, 40 2019); the economic impacts (capital, health, indirect losses from economic disruption) from the 2018 41 California fires were US$149 billion (Wang et al., 2021). Poor air quality from fires caused increased 42 respiratory distress (very high confidence); exposure extends long distances from the fire source (Section 43 14.5.6.3). In addition to public and private property damage and loss, fires have caused irretrievable losses 44 from archaeological and historical sites (Ryan et al., 2012). Post-fire conditions have created unanticipated 45 challenges for communities' water supply operations (Bladon et al., 2014; Návar, 2015; Martin, 2016) by 46 altering water quality and availability (Smith et al., 2011; Bladon et al., 2014; Robinne et al., 2020) or public 47 safety by increasing exposure to mass wasting events after extreme rainfall events (Cui et al., 2019; Kean et 48 al., 2019). California utilities have proactively shut down parts of their electricity grid to reduce risk of fire 49 during extreme weather, and substantial numbers of people will be increasingly vulnerable to this action in 50 the coming decades (Abatzoglou et al., 2020). | 2528 - 252 | Impact | INTANBILE | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 49 50 In North American Arctic marine systems, rapid warming is significant, with cascading impacts beyond 51 polar regions (CCP6), and presents limited opportunities (tourism, shipping, extractive) but high risks 52 (shipping, and fishing industries, Indigenous subsistence and cultural activities) (high confidence )(Gaines et 53 al., 2018; IPCC, 2019b; Samhouri et al., 2019; Free et al., 2020; Holsman et al., 2020) (see sections 14.5.4; 54 14.5.9; 14.5.11;CCP6). Both direct hazards and indirect food web alterations from sea ice loss have 55 imperilled seabirds, marine mammals, small boat operators, subsistence hunters and coastal communities 56 (Sigler et al., 2014; Allison and Bassett, 2015; Huntington et al., 2015; Hauser et al., 2018; Raymond- 57 Yakoubian and Daniel, 2018; Dezutter et al.) (CCP6). Increasingly favourable environmental conditions due ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 14 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 14-29 Total pages: 157 1 to warming combined with shipping and other activities has raised the rate of invasive species movement 2 into the Arctic (Mueter et al., 2011). Sea ice loss due to climate change is expected to accelerate over the 3 next century (14.2, WG1 9.3.1). | 2530 - 253 | Impact | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 9 Loss of coral habitat leads to loss of ecosystem structure, fish habitat, and food for coastal communities and 10 impacts tourism opportunities (14.5.7) (Weijerman et al., 2015a; Weijerman et al., 2015b). Without 11 mitigation to keep surface temperatures below a 2.0ºC increase by the end of the century, up to 99% of coral 12 reefs will be lost. However, 95% of reefs will still be lost even if warming is kept below 1.5ºC (high 13 confidence) (Hoegh-Guldberg et al.; Hoegh-Guldberg et al., 2019a). In Florida, by 2100, an estimated 14 US$24–55B may be lost in recreational use and value derived by people knowing the reef exists and is 15 healthy (Lane et al., 2013; Hoegh-Guldberg et al., 2019b) as coral reefs decline (14.5.9). | 2531 - 253 | ʼrot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGII_Full_Report | 16 17 SLR has led to flooding, erosion and damage to infrastructure along the western Gulf of Mexico, the 18 southeast US coasts, and the southern coast of the Gulf of St Lawrence (14.2) (Daigle, 2006; Lemmen et al., 19 2016; Frederikse et al., 2020) (very high confidence). Mangroves, important nurseries for fish and climate 20 refugia for corals (Yates et al., 2014), are under threat from climate change along the east coast of Mexico 21 (Pedrozo Acuña, 2012). SLR, storm surge and attendant erosion of coastlines and barrier habitats are 22 projected to have large impacts on coastal ecosystems, maritime industries (14.5.9), urban centres and cities 23 (14.5.5) along the Gulf of Mexico, Caribbean Sea, Southeast US, the southern Gulf of St Lawrence and the 24 Pacific Coast of Mexico (Box 14.4) (Semarnat, 2014; Sweet et al., 2017; Vousdoukas et al., 2020). Coastal 25 archaeological and historical sites are especially vulnerable to SLR (Anderson et al., 2017; Hestetune et al., 26 2018; Hollesen et al., 2018). | 2531 - 253 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 3 4 Beaching of massive Sargassum seaweed mats (Sargassum natans and S. fluitans) have been reported across 5 the Caribbean and Gulf of Mexico from 2011-present day, affecting US and Mexico nearshore ecosystems, 6 human health and the tourism industry (Franks et al., 2016; Resiere et al.; Wang et al., 2019). Costs of beach 7 clean-up is high, with Texas spending over USD$2.9 million annually (Webster and Linton, 2013). | 2532 - 2532 | | | |
| IPCC_AR6_WGII_Full_Report | 36 For instance, in 2015 and 2016, extensive, severe bleaching affected more than 30% of corals off the 37 southeast US and a large proportion of US Hawaiian Islands, but had moderate to no impact off the Mexican 38 Yucatan Peninsula (Frieler et al., 2013; Weijerman et al., 2015a; Weijerman et al., 2015b; Cinner et al., 39 2016; van Hooidonk et al., 2016; Hughes et al., 2018; Sully et al., 2019; Williams et al., 2019b). Some reefs 40 are exhibiting recovery following efforts focused at reducing non-climate stressors (e.g. overfishing, nutrient 41 pollution and tourism use). MHWs are increasing in intensity and frequency(Hobday et al., 2016; Smale et 42 al., 2019a) with largest increases in frequency and spatial coverage projected for the Gulf of Mexico, US 43 southern East Coast and US Pacific Northwest (Ranasinghe et al., 2021) and pose a key risk to marine 44 systems in North America (14.5.2, Ch 3, 16,). | 2532 - 253 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 37 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 14 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 14-40 Total pages: 157 1 2 3 Figure 14.6: Climate change impacts on North American fisheries and aquaculture 4 5 6 Warming waters and OA have impacted aquaculture production in North America (high confidence) (Figure 7 14.6) (Clements and Chopin, 2017; Reid et al., 2019; Stewart-Sinclair et al., 2020). Under climate change 8 (RCP8.5), declines in marine finfish and bivalve aquaculture become likely by mid-century (Froehlich et al., 9 2018; Stewart-Sinclair et al., 2020). Adaptation is possible but uncertain (Bitter et al., 2019; Fitzer et al., 10 2019; Reid et al., 2019), especially with increasing extreme events. Nature-based aquaculture solutions (e.g., 11 conservation aquaculture, restorative aquaculture) could aid carbon mitigation and local-level adaptation, 12 especially for seaweed and bivalve culture (Box 14.7) (Froehlich et al., 2017; Froehlich et al., 2019; Reid et 13 al., 2019; Theuerkauf et al., 2019). | 2541 - 254 | ʼrot-Adapt-Mitig-Impac | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 23 24 25 14.5.4.4 Food and Fibre Adaptation: Agriculture, Livestock, and Forestry 26 27 Land management and horticulture approaches that preserve and improve soil structure and organic matter 28 can reduce erosion (high confidence) (Section 14.5.1, 3) (Lal et al., 2011; Bisbis et al., 2018), and preserving 29 biodiversity and water, changing planting dates, and double cropping are effective climate adaptation 30 strategies (Bisbis et al., 2018; Hernandez-Ochoa et al., 2018; Monterroso-Rivas et al., 2018; Wolfe et al., 31 2018). Traditional agriculture inherently includes climate adaptive practices that enhance biodiversity, soil 32 quality and agricultural production (e.g., multiple cultivars, heat-tolerant heritage cattle breeds) (Bermeo et 33 al.; Gomez-Aiza et al., 2017; Ortiz-Colón et al., 2018). Agroecology and agroforestry (Box 14.7) in North 34 America has expanded from (but not replaced) traditional and rural practices in Mexico (Metcalfe et al., ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 14 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 14-46 Total pages: 157 1 2020a) as a sustainable and climate-resilient alternative to industrial agriculture (Schoeneberger et al., 2017) 2 that increases productivity (by 6-65% depending on the crop), enhances microclimatesand provides co- 3 benefits for GHG mitigation (Abbas et al., 2017; Cardinael et al., 2017; Schoeneberger et al., 2017; Snapp et 4 al., 2021). Irrigation is an effective adaptation strategy in key agricultural areas (Miller, 2017; Lund et al., 5 2018) and could stabilize food security in rain-fed regions (e.g., southeastern Mexico) (Spring, 2014); water 6 allocation must balance multiple needs and rights (medium confidence) (14.5.3) (Brown et al., 2015b; Levis 7 et al., 2018; Gomez Diaz et al., 2019). Heritage livestock breeds, changing species, and precision ranching 8 technology may promote ranch and rangelands resilience (Zhao et al., 2013). In loblolly pine plantations in 9 the southern US, effective adaptation includes reducing tree density and, less effectively, shifting to slash 10 pine (Susaeta et al., 2014). Salvage logging following forest disturbances (e.g., insect outbreaks) can increase 11 timber harvest (Bogdanski et al., 2011; USDA Forst Service, 2011; Han et al., 2018; Morris et al., 2018a). | 2547 - 254 | ʼrot-Adapt-Mitig-Impact | | |
| IPCC_AR6_WGII_Full_Report | 35 36 14.5.5.1.3 Sea level rise 37 SLR interacts with shoreline erosion, storm surge and wave action, saline intrusion, and coastal flooding to 38 directly threaten coastal cities and small communities in North America with impacts to public and private 39 buildings and infrastructure, port and transportation facilities, water resources (high confidence) (NOAA 40 National Weather Service, 2017; Boretti, 2019), and cultural heritage sites (Dawson et al., 2020) (Box 14.4). | 2549 - 254 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 28 29 14.5.5.2.3 Sea level rise 30 In the US, many people are projected to be at risk of flooding from SLR (high confidence) (Box 14.4). A 31 projected SLR of 0.9m by 2100 could place 4.2 million people at risk of inundation in US coastal counties, 32 whereas a 1.8-m SLR exposes 13.1 million people (Hauer et al., 2016). In California, under an extreme 2-m 33 SLR by 2100, US$150B (2010) of property or more than 6% of the state's GDP and 600,000 people could be 34 affected by flooding (Barnard et al., 2019). A 1-m SLR would inundate 42% of the Albemarle-Pamlico 35 Peninsula in North Carolina and incur property losses of up to US$14B (2016) (Bhattachan et al., 2018). In 36 nine southeast US states, a 1-m SLR would result in the loss of more than13,000 recorded historical and 37 archaeological sites with over 1,000 eligible for inclusion in the National Register for Historic Places 38 (Anderson et al., 2017). SLR raises groundwater levels by impeding drainage and enhancing runoff during 39 rain events (Hoover et al., 2017); coastal flooding enhances saltwater intrusion affecting drinking water 40 supply in settlements (e.g., coast of Texas) (Anderson and Al-Thani, 2016). | 2550 - 255 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 48 49 In Mexico, crucial coastal tourism cities such as Cancun, Isla Mujeres, Playa del Carmen, Puerto Morelos 50 and Cozumel (MX-SE) are at risk of SLR with an estimated economic impact of US$1.4 –2.3B (Ruiz- 51 Ramírez et al., 2019) (14.5.7.1.12). Negative effects of the "coastal squeeze" phenomena (generated by SLR, 52 land subsidence, sediment deficit, and current urbanization processes) have been documented on tourist 53 destinations along the coasts of Mexican Gulf of Mexico and Mexican Caribbean. Zoning, limiting 54 urbanization along the coastline, and using nature-base solutions (Box 14.7) are alternatives that could be 55 applied to improve the adaptation of these destinations (Martínez et al., 2014; Salgado and Luisa Martinez, 56 2017; Lithgow et al., 2019). | 2550 - 255 | ʼrot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | 11 Projections changes are relative to 2005, which is the central year for the 1994-2014 reference period. Horizontal lines in the boxes represent the median projection, boxes represent 25th to 75th 12 percentile and whiskers the 10th to 90th 13 percentile of SLR projections from all CMIP6 models as well as other lines of evidence (see Table 9.7 in WGI.9 for 14 more details). Two SLR scenarios are provided for lower (SSP 126) and higher emissions (SSP 585), and are consistent 15 with WGI AR6 Interactive Atlas. Numbers and colors (see Table Box14.4.1 for detailed readiness definitions) on the 16 map and in the projections represent sites and status of SLR adaptation progress. Information supporting SLR 17 adaptation status is summarized in Table Box14.4.1. | 2553 - 255 | Prot-Adapt-Mitig- | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | Ocean Basin Site # Area/City Exposure (not exhaustive) Does the area/city have an Adaptation Plan for SLR? If so, are they taking actions to implement it? (Status) Arctic 1 Tuktoyuktuk, CA Infrastructure, municipal services, transportation, homes, 900 people Tuktoyaktuk Coastal Erosion Study completed March 2019. Additional investments in both planning and actual adaptation measures have occurred. Limited financial resources remain a barrier. (Government of Canada, 2020) ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 14 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 14-52 Total pages: 157 Atlantic 2 Prince Edward Island with Lennox Island, CA PEI: residential, industrial and commercial infrastructure. | 2553 - 255 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | 7 Miami, US Homes, port, transportation infrastructure, tourism (hotels, restaurants, beaches) Miami Dade County released a specific SLR Strategy in 2021. Actions in the plan include elevating roads and other infrastructure, designing ways to accommodate more water in and around buildings, building on higher ground and expanding waterfront parks and canals. The plan includes a map with current and planned adaptation projects in the county (Miami�Dade County, 2021). | 2554 - 255 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | 4 5 6 14.5.7 Tourism and Recreation 7 8 Tourism is one of the largest and fastest growing industries in North America, contributing USD$2.5 trillion 9 to North Americas' GDP in 2019 (WTTC, 2018; Duro and Turrión-Prats, 2019). The US is the world's ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 14 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 14-60 Total pages: 157 1 largest tourism economy (USD$1839 billion contribution to global GDP in 2019), Mexico is ranked 9th 2 (USD$196 billion) and Canada 13th (USD$108 billion) (WTTC, 2018). The tourism industry is both 3 impacted by climate change and significantly contributes to it through the emission of GHGs from travel and 4 activities (Becken and Hay, 2007). By 2060 under RCP8.5 Canada and the US are projected to benefit from 5 climate-induced changes in tourism expenditures of up to 92% and 21% respectively, whereas Mexico could 6 experience a 25% decrease (OECD, 2015; Scott et al., 2019a). | 2561 - 256 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 7 8 14.5.7.1 Observed Impacts and Projected Risks of Climate Change 9 10 14.5.7.1.1 Alpine and Nordic skiing, snowmobiling and other winter sports 11 Winter tourism activities with hard limits to adaptation, particularly those that occur at sea level where less 12 precipitation is expected to fall as snow (i.e., Nordic skiing, snowmobiling, snowshoeing), are at the highest 13 risk from climate change and may experience irreversible impacts well before 2°C of warming above pre- 14 industrial levels (high confidence) (Figure 14.9). During record warm winters, alpine ski resorts in eastern 15 Canada experienced reductions in ski season lengths of between 11 and 17 days (Rutty et al., 2017) and 16 resorts in the US Northeast (US-NE) experienced decreased skier visits by 11.6% and reductions in 17 operational profits of 33% amounting to US$40-52 million (Dawson et al., 2009). Even with advanced 18 snowmaking as an adaptation to warmer temperatures, average ski season lengths are projected to decrease 19 8% (RCP2.6, 2050s) to 73% (RCP8.5, 2080s) in Ontario, Canada (CA-ON) (Scott et al., 2019b), 12% 20 (RCP4.5, 2050s) to 22% (RCP8.5, 2080s) in Quebec, Canada (CA-QC), and 13% (RCP 4.5, 2050s) to 45% 21 (RCP 8.5, 2080s) in the US Northeast (US-NE) (Wobus et al., 2017; Scott et al., 2020). Season length for 22 snowmobiling and cross-country skiing is projected to decrease more dramatically (high confidence) by from 23 80% (RCP4.5) to 100% (RCP 8.5) by mid-century (Wobus et al., 2017) (also see CCP5). The number of 24 outdoor skating-days may decrease by 34% in Toronto and Montreal and 19% in Calgary by 2090 under 25 RCP8.5 (Robertson et al., 2015). The skating season length for the Rideau Canal in Ottawa, Canada, a 26 UNESCO heritage site attracting 1.3 million visitors annually, may decrease by 3.8±2.0 days per decade 27 with later opening dates of 2.6±1.5 days per decade (Jahanandish and Alireza, 2019). | 2562 - 256 | Prot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGII_Full_Report | 28 29 14.5.7.1.2 Beach, coral reef, and protected areas tourism 30 Sea level rise, increased storm surge, wave action, algae blooms, extreme air temperatures, and changes in 31 wind and precipitation patterns threaten coastal tourism infrastructure, submerge beaches, erode walking 32 paths on coasts, and impact destination attractiveness, tourism demand, and recreation economies (very high 33 confidence). Warm weather tourism activities, including beach tourism, snorkelling, and national park 34 visitation will have more time to implement adaptation strategies to reduce climate risks as significant and 35 widespread impacts are not expected until 3 to 4°C of warming (Fig 14.9) (Rutty and Scott, 2015; Atzori et 36 al., 2018; Santos-Lacueva et al., 2018; Duro and Turrión-Prats, 2019). Thirty percent of hotels along the Gulf 37 of Mexico and Caribbean Sea are exposed to flooding and 66% are located on eroding beaches (Lithgow et 38 al., 2019). Coral reef cover in Akumal Bay, Mexico decreased by 79% between 2011 and 2014 (Gil et al., 39 2015; Manuel-navarrete and Pelling, 2015). The recreation value of coral reef tourism in Florida, Puerto 40 Rico, and Hawai'i is expected to decrease by 90% by mid-century under RCP8.5 (EPA, 2017) (14.4.2). | 2562 - 256 | Prot-Adapt-Mitig-Impac | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 41 Wildfires and insect outbreaks have contributed to reduced desirability for tourism across forest and 42 mountain regions (Bawa, 2017; Hestetune et al., 2018; White et al., 2020). Visitors to Utah's National Parks 43 declined 0.5 to 1.5% during wildfire years between 1993 to 2015, resulting in US$2.7 to 4.5 million in lost 44 revenue (Kim and Jakus, 2019) (see Box 14.2). Trees damaged by insects have caused campground and 45 hiking trail closures in the western US and Alaska (Arnberger et al., 2018). SLR, flooding, coastal erosion, 46 changing air and sea temperatures, changing humidity, and extreme weather events are putting cultural 47 heritage sites at risks (Fatorić and Seekamp, 2017; Hollesen et al., 2018; Tetu et al., 2019). | 2562 - 256 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 48 49 14.5.7.1.3 Arctic tourism 50 Cruise and yacht tourism in the North American Arctic increased rapidly over the past decade as changes in 51 sea ice has expanded open water areas and season length (Johnston et al., 2016; Pizzolato et al., 2016; 52 Dawson et al., 2018). The risk of a major accident or incident among Arctic-going yachts and some 53 expedition passenger vessels is very high relative to other ships (high confidence) due to the combined 54 increases in mobile ice, especially along the Northwest Passage (Barber et al., 2018a; Howell and Brady, 55 2019; Copland et al., 2021; Lemmen et al., 2021), limited regulation for private yachts (Dawson et al., 2014; 56 Dawson et al., 2017), the propensity for cruise ships to travel into newly ice-free and poorly charted areas, 57 and the increasing number of non-ice strengthened vessels operating in the region (Dawson et al., 2018; ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 14 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 14-61 Total pages: 157 1 Copland et al., 2019; Copland et al., 2021). Compounding risks include a lack of hydrographic charting and 2 the lack of emergency response infrastructure (e.g., spill response, search and rescue, salvage) (Amap, 2017). | 2562 - 256 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 3 Tourism demand for polar bear viewing in Churchill, Manitoba, Canada may change due to climate-related 4 declines in polar bear health (Gil et al., 2015; Manuel-navarrete and Pelling, 2015), but may be offset by 5 'Last Chance Tourism' (LCT), a niche tourism market of individuals who explicitly seek to visit vanishing 6 landscapes and/or disappearing flora and fauna (Lemelin et al., 2010).The ethics of promoting LCT has been 7 questioned considering that more visitation to sensitive sites increases local impacts as well as travel-related 8 emissions (Groulx et al., 2016; Groulx et al., 2019). | 2563 - 256 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 9 10 14.5.7.2 Emerging Responses and Adaptation 11 12 Compared to other economic sectors (see section 14.5.8), the tourism industry has high adaptive capacity 13 (high confidence) (Figure 14.9). Investments in climate-resilient infrastructure within Canadian National 14 Parks have increased visitation rates during the shoulder seasons (Fisichelli et al., 2015; Lemieux et al., 15 2017; Wilkins et al., 2018), regional collaboration among US and Canadian park agencies has enhanced 16 adaptive capacity through integrated planning and management (Lemieux et al., 2015), and technological 17 advancements have reduced the vulnerability of alpine winter sports from warming temperatures (e.g., 18 snowmaking, refrigerated surfaces, chemical additives) (Rutty and Scott, 2015; Scott et al., 2019b; Scott et 19 al., 2020). Snowmaking as an adaptation strategy affects mitigation efforts by increasing the need for energy 20 and fuel (Scott et al., 2019b). | 2563 - 256 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | 28 29 Hard and soft limits to adaptation exist in the tourism sector (Manuel-navarrete and Pelling, 2015). For 30 example, machine-made snow without the use of environmentally harmful chemical additives that are 31 banned in most jurisdictions, can only be made efficiently in temperatures below -2 °C, but projections 32 indicate warming temperatures above this threshold (Wobus et al., 2017; Scott et al., 2019a). Multi-33 jurisdictional adaptation planning for parks and protected areas in the US has been hindered by a lack of 34 funding, communication, and funding trade-offs that could be remedied through coordination (Lemieux et 35 al., 2015). Social inequalities generated by the tourism development process must also be considered by 36 climate-related interventions to avoid the perpetuation of inequalities that may exist, particularly in less 37 developed regions and rapidly developing regions. For example, New developments in Hawai'i, Florida, 38 Quebec, and popular resort areas in Mexico have led to social inequalities through increased property taxes 39 leading to the marginalization of local residents away from these areas in favour of wealthy tourists (Manuel- 40 navarrete and Pelling, 2015) (also see 14.5.9). | 2563 - 256 | Prot-Adapt-Mitig- | INTANBILE | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 41 42 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 14 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 14-62 Total pages: 157 1 2 Figure 14.9: Burning ember of the relative risks to select tourism activities in North America with and without 3 adaptation as a function of global mean surface temperature increase since pre-industrial times. Risks to tourism 4 activities include: 1) season length reductions from warming temperatures for Nordic skiing and snowmobiling, 2) 5 season length reductions from warming temperatures and precipitation changes for alpine skiing, 3) visitor experience 6 changes as a result of warming surface and ocean temperatures for beach tourism and degrading coral reef systems for 7 snorkelling, 4) visitor experience changes related to warming temperatures and changing landscape aesthetic for Parks 8 and Protected Areas. Risks assessed cover all of North America (3, 4), or are specific to certain regions (1, 2). The 9 supporting literature and methods are provided in Supplementary Materials (SM14.4). | 2563 - 256 | Prot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGII_Full_Report | 10 11 12 14.5.8 Economic Activities and Sectors in North America 13 14 Economic sectors highly reliant on climate, such as agriculture, tourism, fisheries, and forestry, have higher 15 levels of exposure and sensitivity (high confidence) and greater overall risk to climate change compared to 16 other economic sectors such as mining, construction, and manufacturing (medium confidence). However, the 17 cascading nature of climate impacts related to trade (Box 14.5), labour productivity (14.5.8.1.5), and 18 infrastructure (14.5.8.1.2) means that there is no economic sector in North America that will be unaffected 19 by climate change (very high confidence) (Figure 14.10). For Canada, this assessment is further supported by 20 the Canadian Climate Assessment (Lemmen et al., 2021). The combined economies of Canada, Mexico and 21 the US represented ~28% of the global GDP in 2019, with the US accounting for almost 90% of the total 22 activity for North America (World Bank, 2020a). The risks posed at different GWLs for any given economic 23 activity or sector are presented in Figure 14.10. By combining expert judgement with a systematic review of 24 the literature for each sector, the information in this Figure represents a broader synthesis, especially for ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 14 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 14-63 Total pages: 157 1 sectors with a smaller literature base and at higher GWLs. The assessment of the risks of climate change on 2 tourism (14.5.7) and the interactions between sectors through trade (Box 14.5) are discussed separately. | 2564 - 256 | Impact | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 16 17 14.5.8.1.2 Transportation 18 Transportation infrastructure, including roads, bridges, rail, air, sea, and pipelines, are highly vulnerable to 19 rising temperatures, SLR, weather extremes, changing ice conditions, permafrost degradation, and flooding 20 (high confidence), resulting in damage, disruption to operations, unsafe conditions, and supply-chain impacts 21 (Board and Council, 2008; Natural Resources Conservation Service; Andrey and Palko, 2017; Jacobs et al., 22 2018; Lemmen et al., 2021) (Box 14.5). In the Mexican states of Veracruz, Tabasco, San Luis Potosí, 23 Chiapas and Oaxaca, 105,000 infrastructure sites, mostly major connecting roads, were found to be at risk of 24 flooding from tropical storms (De la Peña et al. 2018). Low water levels in the Great Lakes has severely 25 impacted US grain transport (Attavanich et al., 2013). High intensity rain events destroyed 1,000km of roads 26 and washed out hundreds of bridges and culverts in 2013 resulting in an estimated CAD$6 billion (2013 27 dollars) in damages and recovery costs in Alberta, Canada (CA-PR) (Palko and Lemmen, 2017). In 2019, the 28 rail line from Winnipeg to Churchill Manitoba, which is the only ground transportation to the community 29 and to Canada's only deep-water Arctic port, was reopened after being closed for over two years due to the 30 cumulative effects of flooding, permafrost degradation, and political challenges (Lin et al., 2020). In the US, 31 the number of heat-related train delays has increased (Bruzek et al., 2013; Chinowsky et al., 2019) and by the 32 end of the century may cause economic losses of US$25 to 45 billion (RCP4.5) or US$35 to 60 billion 33 (RCP8.5) (Chinowsky et al., 2019). Sea ice reduction in the North American Arctic has led to a rapid 34 increase in ship traffic (Huntington et al., 2015; Phillips, 2016; Pizzolato et al., 2016; Huntington et al., 35 2021b; Li et al., 2021) with cascading risks related to invasive species introduction, accident rates, black 36 carbon emissions, underwater noise pollution for marine mammals, and risks to subsistence harvesting 37 activities in Indigenous communities. (Ware et al., 2014; Council of Canadian Academies, 2016, Huntington, 38 2021; Verna et al., 2016; Chan et al., 2019) 39 40 14.5.8.1.3 Energy, oil and gas, and mining 41 Climate change is increasing the demand for electric power for cooling and threatens existing power supply 42 (high confidence) (see 14.5.5). Increased energy demand often occurs during peak energy usage and 43 especially during heat waves (Cruz and Krausmann, 2013; Leong and Donner, 2015). Cooling represented 44 74% of peak electricity demand in Philadelphia on a particularly hot day in July 2011 (Waite et al., 2017; 45 IEA, 2018b). In Canada, warming temperatures are expected to reduce demand for heating by 18 - 33% and 46 increase demand for cooling by 14 - 126% by 2070 compared to 1959-89 and 1998-2014 baseline periods, 47 respectively (Berardi and Jafarpur, 2020). The effects on hydropower are uneven across the region with the 48 potential for increases in capacity in Canada but declines of over 20% in Mexico (RCP4.5 and RCP8.5) 49 (Turner et al., 2017). Electricity demand in the US is projected to increase by 5.3 % per degree C rise in 50 temperature (Hsiang et al., 2017). Energy infrastructure, such as drilling platforms, refineries and pipelines 51 and evacuation routes are also increasingly vulnerable to higher sea levels, hurricanes, storm surges, mobile 52 multi-year sea ice, erosion, inland flooding, wildfires, and other climate-related changes (Zamuda et al., 53 2018). | 2565 - 256 | Prot-Adapt-Mitig-Impac | | INDG |
| IPCC_AR6_WGII_Full_Report | 54 55 Operational efficiency and human safety at mining and energy production sites is expected to be adversely 56 affected by increases in extreme events (Section 14.2), including storms, heavy rains, riverine flooding, and 57 wildfires (high confidence). General remoteness of many mining sites (especially in the North American ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 14 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 14-64 Total pages: 157 1 Arctic) exacerbates risks related to emergency responses to extreme events such as wildfire (medium 2 confidence). The 2016 Fort McMurray wildfire in Alberta Canada forced the evacuation of 88,000 people 3 and the shutdown of mine operations. Damages were minimal because companies had undertaken proactive 4 FireSmart interventions specifically developed for the industry (Council of Canadian Academies, 2019) (see 5 Box 14.1). Onshore oil field production in Tabasco, Mexico, which accounts for 16% of the country's daily 6 output, was interrupted by extensive flooding (Cruz and Krausmann, 2013). Two-thirds of mine operators 7 globally, including major operators in North America, have experienced production challenges related to 8 water shortages and flooding (Carbon Disclosure Project, 2013).Water availability stress due to climate 9 change is lower in Canada than in the US and Mexico and mines in Canada may be less exposed to this risk 10 (World Resourcs Institute, 2012), with some exceptions, i.e., water-intensive oil sands mining in the 11 Athabasca River basin in Canada (Leong and Donner, 2016) (also see 14.5.3).Warming temperatures also 12 has the potential to alter the nature, characteristics and quality of mineral resources such as kaolin or 13 limestone (Phillips, 2016). | 2565 - 256 | Impact | | |

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| Report Title (Year) | Quotation Content | Page(s) | Prot-Adapt-Mitig-Impact* | Intangible** | Indigenous*** |
|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 14 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 14-66 Total pages: 157 1 2 3 4 Figure 14.10: Burning Ember of the relative risks to economic sectors in North America as a function of 5 projected global mean surface temperature increase since pre-industrial times. Impacts on economic sectors 6 include: 1) changing crop yield leading to economic loss for agriculture, 2) changes in the quality and quantity of timber 7 yields, 3) reductions in season length and economic viability for tourism activities, 4) increased maintenance and 8 reconstruction costs to transportation infrastructure, 5) changes in fisheries catch, 6) reduced productivity in mining and 9 energy operations, 6) reduced labour productivity in outdoor construction, and 7) increased maintenance and 10 reconstruction costs to transportation systems. Risks to economic sectors and activities were sometimes assessed across 11 all of North America (3, 4), within specific regions (1, 2), and for specific crops or species (1 - corn and soybean, 2 – 12 cod and pollock). The supporting literature and methods are provided in Supplementary Material (SM14.4). | 2567 - 256 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 19 20 14.5.9.3 Adaptation 21 22 Climate hazards undermine adaptation by damaging livelihoods (high confidence). Many actions that 23 enhance and promote resilient livelihoods can have substantial benefit for adaptation to climate hazards 24 (medium confidence). Livelihoods in the context of climate change are characterized by adjustments that 25 then feedback into the assets that comprise a livelihood. Social capital - in the form of household and 26 community cohesion - facilitates the development of adaptation strategies to the impacts of climate change in 27 rural and urban communities at the household level and for small groups (Barbier, 2014; Nawrotzki et al., 28 2015b; Nawrotzki et al., 2015c). Cultural capital, especially in the form of local knowledge and Indigenous 29 knowledge, can guide adaptation practices in North America (Akpinar Ferrand and Cecunjanin, 2014), 30 preserving Indigenous cultures and enhancing future adaptation and resilience (Pearce et al., 2012 2015; 31 Audefroy and Cabrera Sánchez, 2017) (Box 14.1). In Mexico, rain-water harvesting (practiced by some 32 Mayan communities) and the use of local-traditional varieties of maize have assisted in the adaptation to 33 climate impacts and promoted food security (Akpinar Ferrand and Cecunjanin, 2014; Hellin et al., 2014). | 2573 - 257 | 'rot-Adapt-Mitig-Impa | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 27 28 KR3: Cumulative damages from climate hazards pose a substantial risk to economic well-being and shared 29 prosperity 30 31 Climate change impacts are projected to cause large market and non-market damages (high confidence). By 32 end-of-century under higher GWL scenarios (>4°C), these damages are expected to reach several tens of 33 billions of dollars/annually in Canada and hundreds of billions/annually in the United States. Losses in 34 labour productivity and wages, and damages to coastal properties will be especially large; however, all 35 sectors in the US and most sectors in Canada are projected to see substantial relative damages on high 36 emission pathways by mid to end-of-century compared to lower emission pathways. Economic sectors with 37 hard limits to adaptation (i.e., winter tourism) or that are highly affected by climate variability (i.e., 38 agriculture and fisheries) will be at more risk at lower temperatures than other economic sectors (14.5.7; 39 14.5.8). Strategic implementation of adaptation strategies coupled with lower emissions scenarios result in 40 multi-billion-dollar reductions in economic damages (14.5.8, Box 14.6). | 2577 - 257 | 'rot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | 50 51 KR9: Risks to major infrastructure supporting commerce and trade with implications for sustainable 52 economic development, regional connections, and livelihoods 53 54 Climate change and extreme events are expected to increase risks to the North America economy via 55 infrastructure damage and deterioration (high confidence), disruption to operations, unsafe conditions for 56 workers (medium confidence), and interruptions to international and interregional supply chains (medium 57 confidence) (14.5.8, Box 14.5). These climatic impacts will have cascading implications for local livelihoods, ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 14 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 14-77 Total pages: 157 1 sustainable economic development pathways, regional connectivity and will reinforce pre-existing social 2 inequities (medium confidence). Infrastructure damage will also disrupt economic activities, including 3 manufacturing, tourism, fisheries, natural resource extraction, and energy production (high confidence) (14.5.8). | 2578 - 257 | Impact | INTANBILE | |

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| IPCC_AR6_WGII_Full_Report | 34 35 According to archaeological evidence, however, these adaptation strategies were not always sufficient during 36 times of climate-induced stress. Human remains showing the effects of malnutrition are fairly common, and 37 conflict caused in part by climate-induced shortfalls in farming has left traces that include fortified sites, sites 38 placed in defensible locations, and trauma to human bone. Larger and more hierarchical groups emerged, 39 first in Mesoamerica and then in the US Southwest, Midwest, and Southeast. These groups offered the 40 possibility of buffering poor production in one area with surplus from another, but they also tended to 41 increase inequality within their borders and often attempted to expand at the expense of their neighbours, 42 introducing new sources of potential conflict. Dense hierarchical societies also arose in other areas such as 43 the Northwest coast where agriculture was not practiced but resources such as salmon and roots were 44 abundant and either relatively constant or storable. | 2580 - 258 | 'rot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | 14 15 Still, Indigenous knowledge, and traditional knowledge among Euroamerican farming communities, provide 16 guidelines for how to cope with traditional problems. Contemporary governmental restrictions (such as legal 17 water rights allocations, international borders and tribal lands boundaries) have limited the adaptive capacity 18 that Indigenous societies developed over the centuries. Now human-caused climate forcing, if not mitigated 19 by reducing heat-trapping greenhouse gases, is expected to produce climates in North America that have no 20 local analogs in human history even as it destroys heritage sites that are sources of knowledge about 21 paleoclimates and the diverse ways of coping with them that past people have discovered. Just as past 22 peoples often avoided local climate change by moving on, in a world where mobility options are severely 23 limited a lesson from archaeology and history is that we should use our hard-won knowledge of the causes of 24 climate change to avoid creating futures with no past analogs to provide useful guidance. | 2581 - 258 | 'rot-Adapt-Mitig-Impact | | INDG |
| IPCC_AR6_WGII_Full_Report | 32 33 Progress in Mexico on adaptation implementation at the local level has been extensive (INECC and 34 Semarnat, 2018). Activities include executing programs for relocating infrastructure in high-risk zones in 35 priority tourist sites, incorporating adaptation criteria in public investment projects that involve construction 36 and infrastructure management, water management, application of climate adaptation norms for the 37 construction of tourist buildings in coastal zones, and improving the security of key water, communication, 38 and transportation infrastructure (14.5.5, 14.5.7, 14.5.8). Additionally, local capacity and protocol to respond 39 to extreme weather events as a function of climate change have been integrated more regularly into 40 community-based hazard mitigation plans. States and municipalities in Mexico must have climate policies 41 that are consistent with the guidelines of national strategies (see 14.7.1.5) and state-level programs on 42 climate change, in addition to other state and municipal laws. As a result, these entities have developed and 43 implemented early warning systems designed to protect the population from climate-related risks, such as 44 strong storms and hurricanes (INECC and Semarnat, 2018). | 2584 - 258 | 'rot-Adapt-Mitig-Impa | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII _Full_Report | H H M M Lack of coordination and planning at multiple scales as species redistribute across fishery areas, marine protected zones, and international and jurisdictional boundaries Marine species mortality events Freshwater Resources (14.5.3) Forecasting and warning of harmful algal blooms (HABs) that affect water quality Reduced human exposure to the increased risk of toxins from HABs in the Great Lakes M L�M L- M L- M Financial resources required to enhance water treatment facilities to deal with HABs; technological innovation to improve treatment and removal of HABs; closure of recreational water use Severe human health effects; mortality of aquatic species ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 14 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 14-86 Total pages: 157 Water Availability (14.5.3) Water allocation policies reassessed to enhance equity, sustainability and flexibility in times of shortage through sharing agreements, improved groundwater regulation and voluntary water transfers US Colorado River interstate shortage sharing agreement H H M L�M Complex legal and administrative challenges, heightening lengthy disputes and costly interstate legal battles Depletion of finite groundwater resources and reduced flow in hydrologically connected rivers Food & Fibre (14.5.4) Improved climate resilience through increasing income and harvest/crop portfolio diversification Fishing communities in the US-SW and US-NE through nature-based aquaculture solutions (Messier et al., 2019; Rogers et al., 2019; Young et al., 2019; Fisher et al., 2021) H H M�H M Lack of high resolution and locally tailored climate change information Collapse of fisheries and loss of crops due to excessive warming and extreme events Cities & Infrastructure (14.5.5) Consideration of the value of green infrastructure and natural assets to meet a range of adaptation needs related to flooding, extreme urban heat, SLR, drought Municipal Natural Assets Initiative (MNAI) assists Canadian municipalities to integrate natural assets in financial planning and asset management programs and consider projected climate changes (Municipal Natural Assets Initiative, 2018) H H M L�M Organizations' willingness to take on solutions that are emergent and less tested; capacity for municipalities to undertake the development and assessment this new infrastructure Rate and magnitude of climate changes exceed capacity of natural/green infrastructure to cope Health & Communities (14.5.5, 14.5.6) Access to green spaces, cooler infrastructure, and cooling stations The heatwave plan for Montreal includes visits to vulnerable populations, cooling shelters, monitoring of heat-related illness, and extended hours for public pools (Lesnikowski et al., 2017) H H L�M L- M Lack of effective warning and response systems, ability to reach at-risk populations, building designs, enhanced pollution controls, urban planning strategies, and affordable, resilient health infrastructure Extreme increase heat�related mortality and morbidity Tourism & recreation (14.5.7) Diversification of winter-focused recreation and tourism opportunities Investments in climate-resilient infrastructure within Canadian National Parks have increased visitation rates during the shoulder seasons (Fisichelli et al., 2015; Lemieux et al., 2017; Wilkins et al., 2018) H H M L Social inequalities generated by the tourism development process not considered, such as increased property taxes leading to the marginalization of local residents in favour of wealthy tourists Lack of precipitation that falls as snow particularly in lower elevation areas Commerce & | 2587 - 258 | 'rot-Adapt-Mitig-Impac | INTANBILE | |
| IPCC_AR6_WGII _Full_Report | Sector NbS Actions Benefits References ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 14 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 14-92 Total pages: 157 Coasts Conservation and restoration of barrier habitats, salt marshes, mangroves, coral and oyster reefs, sand dunes, and river deltas; combined natural and built infrastructure, e.g., oyster reef in front of breakwall Wave attenuation; erosion and flood reduction from storm events exacerbated by SLR; novel, created habitats, connectivity; recreation, quality of life (Borsje et al., 2011; Scyphers et al., 2011; Cheong et al., 2013; Pinsky et al., 2013a; Temmerman et al., 2013; Ferrario et al., 2014; Möller et al., 2014; Rodriguez et al., 2014; Spalding et al., 2014; Yates et al.; EPA, 2015b; Grenier et al., 2015; Brandon et al., 2016; Herr and Landis, 2016; Narayan et al., 2016; Sasmito et al., 2016; Ward et al., 2016; Aerts et al., 2018; Beck et al., 2018a; Morris et al., 2018b; Moudrak et al.; Reguero et al., 2018; Sutton-Grier et al., 2018) Watershed approaches such as protecting and restoring forests and wetlands in coastal watersheds, adopting stream buffers in agricultural areas (see agriculture below) Create a less flashy/variable hydrology; reduce sediment, nutrient, hazardous chemical input to coastal waters and reduce eutrophication and other water quality impairments, notably in in deep waters where fish seek refuge from rising sea surface temperatures (Deutsch et al., 2015b) Boesch 2019,CENR 2010 Aquaculture Controlled culture of fish, bivalves, corals and other marine species Enhance, restore and reduce pressure on wild species and ecosystems; Restore threatened species such as coral reef species. | 2593 - 259 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII _Full_Report | 30 Affiliated Tribes of Northwest Indians, 2020: American Indian Communities in the Contiguous United States: Unmet 31 infrastructure needs and the recommended pathway to address a fundamental threat to lives, livelihoods, and 32 cultures. | 2597 - 2597 | | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 15 Climate change is also affecting settlements and infrastructure, health and wellbeing, water and food 16 security, and economies and culture, especially through compound events (high confidence). As of 2017, an 17 estimated 22 million people in the Caribbean live below 6 metres elevation and 50% of the Pacific's 18 population lives within 10 km of the coast along with ≥50% of their infrastructure concentrated within 500 19 metres of the coast {15.3.4.1, 15.3.4.2, 15.3.4.3, 15.3.4.4, 15.3.4.5, 15.3.4.7}. | 2662 - 2662 | | | |
| IPCC_AR6_WGII_Full_Report | 20 21 Tropical cyclones are severely impacting small islands (high confidence). The TC intensity and 22 intensification rates at a global scale have increased in the past 40 years with intensity trends generally 23 remaining positive. Intense TCs including categories 4 and 5 TCs have threatened human life and destroyed 24 buildings and infrastructural assets in small islands in the Caribbean and the Pacific. Among 29 Caribbean 25 islands, 22 were affected by at least one category 4 or 5 TC in 2017. TC Maria in 2017 destroyed nearly all 26 of Dominica's infrastructure and losses amounted to over 225% of the annual GDP. Destruction from TC 27 Winston in 2016 exceeded 20% of Fiji's current GDP. TC Pam devastated Vanuatu in 2015 and caused 28 losses and damages to the agricultural sector valued at USD 56.5 million (64.1% of GDP). Coast-focused 29 tourism is already extremely impacted by more intense TCs. {WGI 11.7.1, 12.4.7 15.2.1, 15.3.3.1, 15.3.3.3, 30 15.3.4.1, 15.3.4.2, 15,3.4.4, 15.3.4.5}. | 2662 - 266 | Impact | | |
| IPCC_AR6_WGII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 15 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 15-5 Total pages: 107 1 Suandaland regions by 2100 for > 3°C warming {15.3.3.3}. This is likely to decrease the provision of resources 2 (e.g. potable water) to the millions of people living on small islands, resulting in impacts upon settlements and 3 infrastructure, food and water security, health, economies, culture, and migration (high confidence) {15.3.3.2, 4 15.3.3.3, 15.3.4.1, 15.3.4.2, 15.4.3, 15.3.4.4, 15.3.4.5, 15.3.4.6, 15.3.4.7}. | 2663 - 266 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 18 19 Future Risks 20 21 The reduced habitability of small islands is an overarching significant risk caused by a combination of 22 several Key Risks facing most small islands even under a global temperature scenario of 1.5 degrees 23 (high confidence). These are loss of marine and coastal biodiversity and ecosystem services; submergence 24 of reef islands); loss of terrestrial biodiversity and ecosystem services ; water insecurity ; destruction of 25 settlements and infrastructure ; degradation of health and well-being ; economic decline and livelihood 26 failure); and loss of cultural resources and heritage. Climate-related ocean changes, including those for slow 27 onset events, and changes in extreme events are projected to cause and/or amplify Keys Risks in most small 28 islands. Identification of Key Risks facilitates the selection of optimal context-specific adaptation options. | 2664 - 266 | 'rot-Adapt-Mitig-Impact | | |
| IPCC_AR6_WGII_Full_Report | 38 39 The unavailability of up-to-date baseline data and contrasting scenarios/temperature levels continue 40 to impair the generation of local-to-regional observed and projected impacts for small islands, 41 especially those that are developing nations (high agreement). Climate model data based on the most 42 recent suite of scenarios (RCPs and especially SSPs) are still not widely available to primary modelling 43 communities in most small island developing nations (high agreement). Coastal sites of small islands are not 44 well-represented in global gridded population and elevation datasets, thereby making estimation of 45 population exposure to SLR difficult. The lack of data continues to impede the development of robust 46 impacts-based modelling output (e.g. for terrestrial biodiversity). Downscaling is pivotal for small islands 47 due to their high diversity which makes generalisation invalid. | 2665 - 266 | Impact | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 20 21 Despite storm-induced erosion prevailing along some shoreline sections, recent studies reaffirmed the 22 contribution of TC and ETC waves to coastal and reef island vertical building through massive reef-to-island 23 sediment transfer (high confidence). For example, TC Ophelia (1958) and Category 5 TC Fantala (2016), 24 which respectively eroded the islands of Jaluit Atoll, Marshall Islands (Ford and Kench, 2016), and Farquhar 25 Atoll, Seychelles (Duvat et al., 2017c), also contributed to island and beach expansion. Likewise, tropical 26 depressions can have constructional effects, as reported on Fakarava Atoll, French Polynesia (Duvat et al., 27 2020b). On Saint-Martin/Sint Maarten and Saint-Barthélemy, the 2017 hurricanes, which caused marked 28 shoreline retreat at most beach sites, also allowed beach formation and beach ridge development along some 29 natural coasts (Duvat et al., 2019a; Pillet et al., 2019). Similarly, El Niño and La Niña were involved in rapid 30 and highly contrasting shoreline changes (high confidence), including reef island accretion in the Ryukyu 31 Islands, Japan (Kayanne et al., 2016), beach shifts on Maiana and Aranuka Atolls, Kiribati (Rankey, 2011), 32 and beach erosion on Hawaii, USA (Barnard et al., 2015). These contrasting shoreline responses were 33 respectively due to coral reef degradation from past bleaching events providing material to islands, wave 34 directional shifts, and increased wave energy. The role of bleaching events in increasing short-term sediment 35 generation in atoll contexts was confirmed by a study conducted on Gaafu Dhaalu Atoll, Maldives, which reported an increase of sediment production from ~0.5 kg CaCO3 m–2 yr-1 to ~3.7 kg CaCO3 m-2 yr-1 36 37 between 2016 (pre-bleaching) and 2019 (bleaching + 3 years) (Perry et al., 2020). | 2674 - 267 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 24 25 Satellite data and local field studies at 3351 sites in 81 countries including small islands show that not all 26 coral reefs are equally exposed to severe temperature stress events, and even similar coral reefs exposed to 27 similar conditions show local and regional variation and species-specific responses (Sully et al., 2019). There 28 is great variability in terms of sensitivity of corals to climate change, as also demonstrated in the Comoros 29 Archipelago (Cowburn et al., 2018), in the Pacific (Fox et al., 2019; Mollica et al., 2019; Romero-Torres et 30 al., 2020) and globally (Sully et al., 2019; McClanahan et al., 2020). It has been hypothesised that low- 31 latitude tropical reefs bleached less than those in higher latitudes because: (i) of the geographical differences 32 in species composition, (ii) of the higher genotypic diversity at low latitudes, and (iii) some corals were pre- 33 adapted to thermal stress because of consistently warmer temperatures at low latitude prior to thermal stress 34 events (Sully et al., 2019). However, latitudinal variation was not reported in other global surveys of coral 35 bleaching occurrence (Donner et al., 2017; Hughes et al., 2017a; Hughes et al., 2017b; McClanahan et al., 36 2019). Ainsworth et al. (2016) and Ateweberhan et al. (2013) showed that coral bleaching can be mitigated 37 by pre-exposure to elevated temperatures. Regionally, recovery is also highly variable. While some reefs in 38 the Seychelles and Maldives were shown to recover to pre-disturbance levels of coral cover after previous 39 bleaching events (Box 15.1; Pisapia et al., 2016; Koester et al., 2020), other reefs underwent seemingly 40 permanent regime shifts toward domination by fleshy macro algae (Graham et al., 2015), or major declines 41 in carbonate budgets, and thus the capacity of reefs to sustain vertical growth under rising sea levels (Perry 42 and Morgan, 2017). | 2675 - 267 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | 11 12 Since 2011, the Caribbean region has been experiencing unprecedented influxes of the pelagic seaweed 13 Sargassum. These extraordinary sargassum 'blooms' have resulted in mass strandings of sargassum 14 throughout the Lesser Antilles, with significant damage to coastal habitats, mortality of seagrass beds and 15 associated corals (van Tussenbroek et al., 2017), as well as consequences for fisheries and tourism. Whether 16 or not such events are related to long-term climate change remains unclear, however it has been suggested 17 that the influx may be related to strong Amazon discharge, enhanced West African upwelling, together with 18 rising seawater temperatures in the Atlantic (low confidence) (Oviatt et al., 2019; Wang et al., 2019). Since 19 2011, the Pacific atoll nation of Tuvalu has also been affected by algal blooms, the most recent being a large 20 growth of Sargassum on the main atoll of Funafuti, and this phenomenon has been related to anthropogenic 21 eutrophication and high seawater temperatures (De Ramon N'Yeurt and Iese, 2014). | 2676 - 267 | Impact | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 50 51 Marine flooding is expected to destroy habitats of coastal species, particularly range-restricted coastal and/or 52 single-island endemics (many already listed as at least 'threatened' by the International Union for 53 Conservation of Nature [IUCN]) within the limited terrain on atoll islands. These species have limited 54 opportunities to accommodate such direct impacts of climate change apart from shifting further inland or to 55 other neighbouring atolls which might have favourable habitat. However, fragmentation of habitat due to 56 anthropogenic activity may hinder migration further inland, while shifting to neighbouring islands is not 57 viable due to the water barrier between islands (high confidence) (Bellard et al., 2013b; Wetzel et al., 2013; ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 15 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 15-22 Total pages: 107 1 Kumar and Tehrany, 2017). Additionally, migratory birds, which use small islands (e.g. atolls) for stopovers 2 or breeding/nesting sites, are projected to become impacted. Within the Mediterranean and Caribbean, 3 significant losses to coastal wetlands - critical habitat for migratory birds has already been observed, with 4 further significant habitat losses, redistribution and changes in quality being projected across island systems 5 such as the Bahamas (Caribbean) and Sardinia (Mediterranean) (Vogiatzakis et al., 2016; Wolcott et al., 6 2018). | 2680 - 268 | 'rot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | 41 Continued high rates of habitat loss and degradation have been reported for many small islands as natural 42 habitats continue to be cleared to meet increasing demands upon natural resources from rising human 43 populations, agriculture, urbanisation, unsustainable tourism, overgrazing and fires. This increases the 44 vulnerability of ecosystems within especially oceanic islands — where isolation has given rise to high levels 45 of endemism but simple biotic communities, with low functional redundancy (Box CCP1.1). There is high 46 confidence that climate change may exacerbate the effects of this habitat loss upon the biodiversity of these 47 islands as the climate refugia (Table 15.3) and the upslope shifts of range-restricted, dispersal-limited and 48 poorly competitive species, confined within narrow latitudinal (and decreasing altitudinal) gradients, are 49 increasingly challenged by fragmented and degraded landscapes (e.g., Struebig et al., 2015a; IPBES, 2019). | 2681 - 268 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 55 56 Analyses of historical and current threats indicate that IAS and disease have been the primary drivers of 57 insular extinctions in modern history (Bellard et al., 2016). Impacts of IAS on islands are projected to ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 15 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 15-23 Total pages: 107 1 increase with time due to synergies between climate change and other traditional drivers such as increasing 2 global trade, tourism, agricultural intensification, over exploitation and urbanisation (Bellard et al., 2014; 3 Russell et al., 2017). Changing climate conditions may not necessarily increase the rate of IAS introductions 4 but is expected to improve chances of IAS establishment via (i) altering IAS transport and introduction 5 mechanisms, (ii) increasing the impacts and distributions of existing IAS and (iii) altering the effectiveness 6 of existing control strategies (Hellmann et al., 2008; Russell et al., 2017). These are likely to enhance IAS 7 impacts on islands including: restructuring of ecological communities leading to declines and 8 extinctions/extirpations in flora and fauna, habitat degradation, declining ecosystem functioning, services 9 and resilience, and in extreme cases, potential community homogenisation (high confidence) (Russell and 10 Blackburn, 2017; IPBES, 2019). Given the high degree of endemicity within oceanic islands and their 11 associated vulnerabilities, such exacerbation by changing climate pose a serious threat to decreasing global 12 biodiversity (medium to high confidence) (van Kleunen et al., 2015). | 2681 - 268 | Impact | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 57 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 15 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 15-26 Total pages: 107 1 15.3.4.3 Water Security 2 3 Climate change impacts on freshwater systems frequently exacerbate existing pressure, especially in 4 locations already experiencing water scarcity (Section 15.3.3.2 and Cross-Chapter Box INTERREG in 5 Chapter 16; Schewe et al., 2014; Holding et al., 2016; Karnauskas et al., 2016), making Water Security a 6 Key Risk (KR4 in Figure 15.5) in small islands. Small islands are usually environments where demand for 7 resources related to socio-economic factors such as population growth, urbanisation and tourism already 8 place increasing pressure on limited freshwater resources. In many small islands, water demand already 9 exceeds supply. For example, in the Caribbean, Barbados is utilising close to 100% of its available water 10 resources and St. Lucia has a water supply deficit of approximately 35% (Cashman, 2014). On many 11 Mediterranean islands, water demand regularly outstrips supply as a result of low average precipitation 12 coupled with increasing water demand from economic activities such as irrigated agriculture and tourism 13 (Hof et al., 2014; Papadimitriou et al., 2019). | 2684 - 268 | Impact | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 48 49 Many small-island economies are sustained by tourism and have invested heavily in associated infrastructure 50 and capacity building (Cannonier and Burke, 2018). Some rural island communities have become dependent 51 on tourism to the point that it would be difficult to revert to subsistence living (Lasso and Dahles, 2018). | 2687 - 2687 | | | |
| IPCC_AR6_WGII_Full_Report | 52 Coast-focused (beach-sea) tourism in island contexts is already being impacted by beach erosion, elevated 53 high SST causing coral bleaching, and associated marine-biodiversity loss, as well as more intense TCs 54 (Tapsuwan and Rongrongmuang, 2015; Parsons et al., 2018; Wabnitz et al., 2018). The Covid-19 pandemic 55 travel disruption significantly affected Caribbean islands tourism sector by reducing incomes that would 56 have been used to enhance climate resilience (Sheller, 2020). Many tourism interests downplay the impacts 57 and future risks from climate change (Shakeela and Becken, 2015), a position that may be borne out by ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 15 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 15-29 Total pages: 107 1 sustained/rising demand for small island vacationing in some locales (Katircioglu et al., 2019). A way 2 forward is for island tourism to emphasize its low-carbon and sustainable attributes, and to encourage 3 smaller-scale eco-friendly holiday opportunities (Lee et al., 2018), in other words for island nations to 4 embrace a 'blue economy' in line with SDG14 to conserve and utilise their oceans for sustainable futures 5 (Hampton and Jeyacheya, 2020; Hassanali, 2020). | 2687 - 268 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 42 43 Even where settlement locations and livelihoods remain secure, an increase in health diseases, decrease in 44 the availability of potable water, and increasing exposure to extreme events may reduce habitability (Section 45 15.3.4.9.2; Campbell and Warrick, 2014; Storlazzi et al., 2018). For example, the Fijian coastal community 46 of Vunidogoloa made the decision to relocate in response to regular inundation during high tides. Raising 47 houses on stilts and constructing a seawall failed to prevent regular flood damage to buildings and the entire 48 community eventually relocated as a 'last resort' adaptation measure to a site within customary land. The 49 availability of customary land for the new site was a key factor of success in this relocation example ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 15 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 15-31 Total pages: 107 1 although this will not guarantee success in every case as relocation may expose communities to new risks 2 (McNamara and Des Combes, 2015; Piggott-McKellar et al., 2019a). | 2689 - 269 | 'rot-Adapt-Mitig-Impa | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 3 4 15.3.4.7 Culture 5 6 Small island societies have developed IKLK based responses to living in dynamic environments susceptible 7 to climate variability and extremes, which are based in broader systems of culture and heritage (high 8 confidence) (Barnett and Campbell, 2010; Lazrus, 2015; Nunn et al., 2017b; Bryant-Tokalau, 2018b; Nalau 9 et al., 2018b; Perkins and Krause, 2018). As expanded upon in Section 15.6.5 cultural resources are thought 10 to play an important role in climate change adaptation on small islands through contributing to adaptive 11 capacity and resilience (McMillen et al., 2014; Petzold and Ratter, 2015; Nunn et al., 2017b; Warrick et al., 12 2017; Falanruw, 2018; Mondragón, 2018; Neef et al., 2018; Parsons et al., 2018; Perkins and Krause, 2018; 13 Hagedoorn et al., 2019; 2020a) (robust evidence, medium agreement). Thus, loss of culture (KR8 in Figure 14 15.5) threatens adaptive capacity. | 2690 - 269 | Prot-Adapt-Mitig- | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 27 28 The unquantifiable and highly localised cultural losses resulting from climate drivers are less researched and 29 less acknowledged in policy than physical and economic losses (Karlsson and Hovelsrud, 2015; Thomas and 30 Benjamin, 2018a). In the Bahamas, prolonged displacement of the entire population of Ragged Island 31 following Hurricane Irma (2017) highlighted the cultural losses that can result from climate-induced 32 displacement from ancestral homelands. Threats to identity, sense of place and community cohesion resulted 33 from displacement, although all were important foundational features of the Islanders' self-initiated 34 rehabilitation efforts and eventual return. Nonetheless, non-economic losses were not accounted for by 35 policy addressing displacement (Thomas and Benjamin, 2018a). In the case of Monkey River Village in 36 Belize, coastal erosion is threatening the community's cemetery. Residents place significant spiritual and 37 emotional value on the cemetery which serves important community functions, and thus, threats to it are 38 perceived to be serious and necessary to be taken into account in any planned response (Karlsson and 39 Hovelsrud, 2015). A similar situation exists on Carriacou in the West Indies where culturally and historically 40 significant archaeological sites are being lost due to coastal erosion caused by a combination of sand mining 41 and extreme climate-ocean events exacerbated by SLR (Fitzpatrick et al., 2006). | 2690 - 2690 | | INTANBILE | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 42 43 Population and settlement concentration in coastal areas and high exposure to climate-driven coastal hazards 44 on small islands mean that threats to tangible cultural heritage (archaeological sites, buildings, historic sites, 45 UNESCO World Heritage Sites etc.) are high (Marzeion and Levermann, 2014; Reimann et al., 2018), 46 although few studies examine this issue specifically in a small island context. On the island of Barbuda, 47 archaeological sites containing important information on historical ecology and climatic shifts are at risk 48 from coastal erosion and hurricanes. This loss of heritage represents identity loss, as “learning about the past 49 is a crucial exploration of self that grounds and connects people to places” (Perdikaris et al., 2017)(p. 145). | 2690 - 269 | Impact | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 50 Loss and damage to heritage sites may also impact tourism and thus have significant economic impacts for 51 narrow small island economies (Section 15.3.4.5). | 2690 - 269 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 20 21 22 The 1997-1998 ENSO event was severe in the Maldives and as a result the living coral cover dropped to 23 <10% (Bianchi et al., 2003). Recovery was still in progress in 2004 when the tsunami caused further 24 (although not quantitatively assessed (Gischler and Kikinger, 2006)) damage to the reef ecosystem. Post- 25 1998 recovery ultimately took 15 years, (i.e., longer than following the 1987 ENSO event, after which 26 recovery had only taken a few years) and also longer than in the neighbouring undisturbed Chagos atolls, 27 thereby suggesting the alteration of the recovery capacity of the reef ecosystem by human-induced reef 28 degradation and climate change (Morri et al., 2015; Pisapia et al., 2017). Mid-2016, a new ENSO event 29 occurred, which reduced living coral cover by 75% (Perry and Morgan, 2017). Future recovery of the reef 30 ecosystem, which is critical to both current livelihoods and economic activities (especially diving-oriented 31 tourism and fishing) and to long-term island persistence, will mainly depend first on the frequency and 32 magnitude of future bleaching events, which are expected to increase due to ocean warming, and second on 33 the highly variable effects of anthropogenic disturbances locally (Perry and Morgan, 2017; Pisapia et al., 34 2017; Duvat and Magnan, 2019b). | 2691 - 269 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 22 23 The loss of mangroves (Branoff, 2018; Walcker et al., 2019; Taillie et al., 2020) and terrestrial forests 24 (Eppinga and Pucko, 2018; Feng et al., 2018; Hu and Smith, 2018; Van Beusekom et al., 2018) exacerbated 25 the cyclone-induced economic crisis. In the most affected islands, the destruction of buildings and 26 outmigration generated a significant loss of tangible (e.g., museums) and intangible (e.g., traditional artistry) 27 cultural heritage (Boger et al., 2019). Prolonged displacement of entire island populations (e.g., Ragged 28 Island, the Bahamas; Barbuda) caused “non-economic loss and damage”, including threats to health and ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 15 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 15-34 Total pages: 107 1 well-being, and loss of culture, sense of place and agency (Thomas and Benjamin, 2019), which may further 2 exacerbate the long-term vulnerability of concerned communities. | 2692 - 269 | Impact | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 24 25 These KRs include loss of marine and coastal biodiversity and ecosystem services (high confidence) (KR1; 26 for details on KR coverage, see Section 15.3.3.1); submergence of reef islands (low confidence) (KR2; 27 Section 15.3.3.1.1); loss of terrestrial biodiversity and ecosystem services (high confidence) (KR3; Section 28 15.3.3.3); water insecurity (medium-high confidence) (KR4; Section 15.3.4.3); destruction of settlements and 29 infrastructure (high confidence) (KR5; Section 15.3.4.1); degradation of human health and well-being (low 30 confidence) (KR6; section 15.3.4.2); economic decline and livelihood failure (high confidence) (KR7; 31 Sections 15.3.4.4 and 15.3.4.5); and loss of cultural resources and heritage (low confidence) (KR8; Section 32 15.3.4.7). | 2694 - 269 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 48 49 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 15 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 15-36 Total pages: 107 1 2 Figure 15.5: Key Risks in small islands. KR1 to 8 are interconnected as shown by arrows, which causes risk 3 accumulation leading to reduced island habitability. The main interconnections are shown in this figure: for example, 4 loss of marine and coastal and terrestrial biodiversity and ecosystem services (KR1 and KR3, respectively) are 5 projected to cause the submergence of reef islands (KR2), water insecurity (KR4), destruction of settlements and 6 infrastructure (KR5), degradation of human health and well-being (KR6), economic decline and livelihood failure 7 (KR7), and loss of cultural resources and heritage (KR8). Importantly, Key Risks result from both direct effects (e.g. | 2694 - 269 | Impact | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 15 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 15-41 Total pages: 107 1 2 3 4 Figure 15.7: Adaptation measures implemented to reduce coastal risks in small islands. Panel 1 provides examples of 5 implementation of different types of measures aimed at reducing coastal erosion and flooding. The measures include no 6 response (no intervention, widespread in small islands), hard protection through the construction of engineering-based 7 structures, accommodation through dwelling and infrastructure raising, planned retreat, advance (i.e. especially island 8 raising) and ecosystem-based measures, in three small island regions, the Indian and Pacific Oceans and Caribbean. It 9 highlights the prevalence of no response, hard protection and the increasing use of ecosystem-based measures. Based on 10 the example of two beach sites in Mauritius (Mon Choisy in the north and Saint-Félix in the south), panel 2 shows that 11 the measures used at a given coastal site evolve over time (e.g., from no response to hard protection, and then planned 12 retreat and ecosystem-based measures) and that recent DRR (Saint-Félix) and adaptation (Mon Choisy) projects often 13 combine several types of measures, including retreat and ecosystem-based measures (Duvat et al., 2020a). Together, 14 panels 1 and 2 emphasize the diversity and increasing complexity of the measures implemented in small islands. | 2699 - 270 | rot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | 25 26 15.5.6 Livelihood Responses 27 28 Communities across small islands are adapting to the impacts of climate change across a range of livelihood 29 activities. Coastal fishers have adapted by employing several activities ranging from diversification of 30 livelihoods to changing fishing grounds and considering weather insurance (Blair and Momtaz, 2018; 31 Lemahieu et al., 2018; Karlsson and McLean, 2020; Turner et al., 2020). In Antigua and Vanuatu, fishers 32 have undertaken adaptation in response to increases in air and ocean temperature, increases in wind and 33 changes in rainfall. In Antigua, adaptation strategies amongst coastal fishers have included investments in 34 improved technologies and equipment, changing fishing grounds, and seeking better training and education 35 (Blair and Momtaz, 2018). In Efate (Vanuatu) the majority (87%) of the fishermen used livelihood 36 diversification as an adaptation strategy whereas 53% also searched for new fishing areas as a result of the 37 changing conditions (Blair and Momtaz, 2018). In Southwest Madagascar, due to deteriorated reef 38 conditions, coastal fishermen now go further offshore to catch fish or have adapted their fishing techniques, 39 while others closer to the tourism markets, have opted for livelihood diversification (Lemahieu et al., 2018). | 2701 - 270 | rot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | 12 13 The tourism sector is increasingly a major source of cash-based livelihoods across small islands. Despite the 14 high vulnerability and sensitivity of island tourism to climate change at a national scale (Scott et al., 2019), 15 there is evidence from the South Pacific that local tourism operators' adaptive capacity is high due to socio- 16 cultural factors. In Samoa, adaptive capacity consists of accommodation providers' social networks, 17 resources, past experiences and understanding of environmental conditions, and remittances as a form of 18 informal insurance (Parsons et al., 2017). The adaptive capacity of Tongan tour operators is strengthened by 19 high climate change awareness, strong social networks and remittances as well as perceived high resilience 20 against climate change (van der Veeken et al., 2016). | 2702 - 270 | Prot-Adapt-Mitig- | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 21 22 Evidence from Vanuatu shows that climate risk to tourism destinations is influenced by multiple, 23 interconnected economic, socio-cultural, political, and environmental factors suggesting that holistic 24 approaches are needed to reduce risk and avoid negative knock-on effects (Loehr, 2019). Tourism can 25 strengthen mechanisms that reduce vulnerability and increase adaptive capacity of the wider destination, 26 such as providing adaptation finance, investing in education and capacity building, and working with nature 27 (Loehr, 2019).Examples include numerous EBA initiatives in the Caribbean including Marine Protected 28 Areas in St. Lucia and Jamaica (Mycoo, 2018a). In Vanuatu, tourism businesses are engaged in establishing 29 Marine Protected Areas to address multiple risks from climate change, population growth and development 30 (Loehr et al., 2020). In the Seychelles, coral restoration programmes and mangrove reforestation are 31 promoted through public-private partnerships, generating new opportunities for wetland-tourism livelihoods 32 (Khan and Amelie, 2015). | 2702 - 270 | rot-Adapt-Mitig-Impa | | |

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| IPCC_AR6_WGII_Full_Report | 33 34 The willingness of tourism businesses to finance adaptation measures varies. Islands have developed 35 building codes which consider impacts from sea level rise but these are often not enforced enforced (Hess 36 and Kelman, 2017). In cases where tourist resorts have been part of climate adaptation projects, such as 37 funding for hard coastal protection infrastructure, the resort owners find that these diminish the aesthetics of 38 the beach destination (Crichton and Esteban, 2018). Adaptation taxes and levies imposed on tourism can 39 provide funding (Mycoo, 2018a) as The Environmental Protection and Tourism Improvement Fund Act, 40 2017 of British Virgin Islands shows (Smith, 2017). A lack of interaction between tourism and climate 41 change decision makers is a commonly identified issue (Becken, 2019; Mahadew and Appadoo, 2019; Scott 42 et al., 2019). A number of adaptation measures are recommended in the literature such as increasing climate 43 change research, education and institutional capacities; product and market diversification away from coastal 44 tourism to include terrestrial-based experiences and heritage tourism, and mainstreaming adaptation in 45 tourism policies and vice versa (e.g., to include appropriate planning guidelines for tourism development, 46 coastal setbacks and environmental impact assessments (Mycoo, 2018a; Becken et al., 2020) Thomas et al., 47 2020; van der Veeken et al., 2016). | 2702 - 270 | 'rot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | 24 25 In the Caribbean small islands such as Jamaica and St. Lucia, and also in the Pacific, barriers to 26 mainstreaming adaptation include competing development priorities, the absence of planning frameworks or 27 'undetected' overlaps in existing frameworks, serious governance flaws linked to the prevalence of 28 corruption and corrupt people in political and public life, and insufficient manpower and human resources, 29 linked to countries' financial capacity (Robinson, 2018b). In addition, the lack of strong governance 30 mechanisms for urban planning have contributed to urban sprawl and expansion that has increased the 31 number of informal settlements, which together with population growth are driving Caribbean small islands 32 to their limits (Enríquez-de-Salamanca, 2018; Mycoo, 2018a; Mycoo, 2018b). In the Pacific, only a few 33 countries have embedded climate change adaptation in existing legislation despite the overall regional 34 agreement to A New Song for Coastal Fisheries - Pathways to Change: the Noumea Strategy' to improve 35 coastal fisheries management in a changing climate (Gourlie et al., 2018). Many climate change specific 36 initiatives across small islands have a unidirectional focus on climate risks and shift limited resources away 37 from other important development objectives (Baldacchino, 2018). Local level plans are often overlooked: 38 for example, in Mauritius, local level climate adaptation plans are currently nearly non-existent while district 39 councils have rarely been successful in even accessing international adaptation finance (Williams et al., 40 2020). In Samoa, several national level programs on adaptation have had difficulties in engaging with the 41 local level even if the decision-making powers on actual land management sit within the communities 42 (McGinn and Solofa, 2020). | 2704 - 270 | 'rot-Adapt-Mitig-Impa | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 43 44 Adaptation governance is also complicated further by the multitude of stakeholders involved, with differing 45 agendas and priorities. In the Bahamas, private properties have significant say in how and what adaptation 46 measures they decide to pursue and are not well regulated, with the tourism sector in particular dominated 47 mainly by external investors (Petzold et al., 2018). Social organisations, such as the churches, that have 48 significant influence in many Oceanic countries, are engaging in climate change discussions and governance. | 2704 - 270 | Prot-Adapt-Mitig- | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 23 24 Countries including the Seychelles and Maldives have developed national climate change plans that 25 recognize linkages to food security, health and disaster risk reduction, although these-face significant 26 resourcing issues when it comes to implementation (Techera, 2018). National level plans, such as National 27 Adaptation Plans of Action (NAPAs), increasingly could include local government engagement and have a 28 stronger focus on urban centres and adaptation (Mycoo, 2018a). Building codes act as supportive enablers 29 for adaptation governance: requiring more hurricane-resistant housing in the Caribbean, including incentives 30 for informal settlements to build in a more resilient manner, can achieve multiple development and 31 adaptation outcomes (Mycoo, 2018a). In Dominica, a Climate Resilience Executing Agency of Dominica 32 (CREAD) established in 2019, aims to enable stronger climate resilience by bringing all sectors and services 33 together for more effective coordination (Turner et al., 2020). Improvements in cross sectoral and cross 34 agency coordination are creating opportunities for improved disaster preparedness and resilience measures in 35 Vanuatu (Webb et al., 2015). A range of mechanisms also exists in the tourism industry: adaptation taxes 36 and improved building regulations could reduce risk drastically for example in the Caribbean region (Mycoo, 37 2018a). | 2705 - 270 | 'rot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | 12 Social networks also function as a source of informal microfinance where extended family members send 13 back remittances from overseas to their families and communities especially after disasters. In Samoa 14 Indigenous tourism operators receive remittances from overseas family members (Crichton and Esteban, 15 2018; Parsons et al., 2018), with similar processes observed among atoll communities in the Solomon 16 Islands (Birk and Rasmussen, 2014), Vanuatu (Handmer and Nalau, 2019) and Jamaica (Carby, 2017). | 2707 - 2707 | | INTANBILE | INDG |

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| IPCC_AR6_WGII_Full_Report | 10 11 Workshops and training are seen as crucial at the local scale to build communities' capacity to take action 12 and to integrate climate change considerations to the broader development processes (Remling and 13 Veitayaki, 2016), although purely workshop-based short-term capacity building in adaptation has been 14 questioned (Conway and Mustelin, 2014; Lubell and Niles, 2019). More interactive community engagement 15 strategies could include "participatory three-Dimensional modelling (P3DM), participatory video, 16 development of photo journals, and civil society plans" (Beckford, 2018, p. 46) that enables broader 17 engagement. In Fiji, Laje Rotuma youth EcoCamps have been used to engage younger Fijians to understand 18 adaptation and increasing environmental stewardship with good outcomes (McNaught et al., 2014). In Palau, 19 Camp Ebiil provides a culturally-based platform for younger generations to learn about nature and culture in 20 an interactive camp (Singeo, 2011). Vanuatu's Volunteer Rainfall Observer Network in turn engages 21 volunteers to record their rainfall observations, demonstrating the use of IKLK that can be integrated with 22 contemporary weather forecasting (Chand et al., 2014). Likewise, initiatives such as ePOP Petites Ondes 23 Participatives aim to develop a citizen network to share environmental information (e.g., via minivideos on 24 smartphones). Across the Pacific, projects such as the European Union Pacific Technical Vocational 25 Education and Training on Sustainable Energy and Climate Change Adaptation Project (EU PacTVET), 26 have sought to increase capacity of Pacific islanders in disaster risk management and climate adaptation 27 (Hemstock et al., 2018). | 2708 - 270 | 'rot-Adapt-Mitig-Impa | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 42 43 The Caribbean Climate Online Risk and Adaptation tool has been developed to assist the tourism industry in 44 producing "climate-sensitive developments" (Mackay and Spencer, 2017,p. 55). Though some authors 45 conclude on the low climate awareness/understanding among small islanders (Middelbeek et al., 2014; 46 Betzold, 2015; Petzold et al., 2018), others indicate that many Caribbean islanders are acutely aware of past 47 storm events (i.e., social memory) and have a certain degree of self-reliance, which creates the capability to 48 multi-task and cope with limited resources (Petzold and Magnan, 2019). There is, however, a disconnect 49 between knowledge, attitudes and practices—knowledge sharing and learning need to be improved along 50 with the take-up of an evidence-based decision-making approach (Lashley and Warner, 2013; Petzold et al., 51 2018; Saxena et al., 2018). | 2708 - 270 | 'rot-Adapt-Mitig-Impa | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 52 53 15.6.5 Culture 54 55 Culture can be defined as "material and non-material symbols that express collective meaning" (Adger et al., 56 2014, p. 762) and includes worldviews and values, how individuals and communities relate to their 57 environment, and what they perceive to be at risk and in need of adaptation (McNaught et al., 2014; Nunn et ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 15 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 15-50 Total pages: 107 1 al., 2014; Remling and Veitayaki, 2016; Nunn et al., 2017bGranderson, 2017; Neef et al., 2018; Oakes, 2 2019). In small islands, culture plays an important role in individual and community decision-making on 3 adaptation both as an enabling factor and as a barrier (robust evidence, high agreement) (Nunn et al., 2017b; 4 Parsons et al., 2017; Neef et al., 2018; Piggott-McKellar et al., 2020). The concept of Vai Nui as the 5 interconnectedness of Pacific Islanders continues to support the collective agency to plan and undertake 6 adaptation efforts in the region (Hayward et al., 2019). In Samoa, the principles of Fa'asamoa (the Samoan 7 way of life) impacts on how decisions are made, including the role of the aiga (extended family) that is a 8 web of local, national and transnational kinship networks (Parsons et al., 2018). Traditional village council 9 structures and land stewardship enables an expanded range of coastal adaptation options in Samoa, including 10 potential relocation, but at the same time may limit participation of all social groups in adaptation decision 11 making (Crichton et al., 2020). In Dominica, in the aftermath of Hurricane Maria (2017), social capital in the 12 form of transboundary nearby island networks enabled some communities to recover faster from the disaster 13 including access to more livelihood opportunities and assets (Turner et al., 2020). | 2708 - 270 | 'rot-Adapt-Mitig-Impa | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 14 15 Yet, culture is often overlooked in adaptation policies and plans. For example, in the National 16 Communications of 16 SIDS, only one country (Cook Islands) reported adaptation actions that addressed 17 social issues, culture, and heritage (Robinson, 2018b). Externally-driven adaptation efforts in rural small- 18 island communities that exclude community priorities, ignore or undervalue IKLK, and are based on secular 19 western/global worldviews (Donner and Webber, 2014; Prance, 2015; McNamara et al., 2016; Nunn et al., 20 2017b; Schwebel, 2017; Mallin, 2018; Nunn and McNamara, 2019; Piggott-McKellar et al., 2019b) are often 21 less successful (high agreement, medium evidence). The World Bank Kiribati Adaptation Program (KAP) for 22 example builds mainly on western knowledge and science despite consultations with the Kiribati 23 communities (Prance, 2015). Yet, in many contexts most land and knowledge is embedded in traditional 24 governance and culture while adaptation plans and decisions are made elsewhere on how that land should be 25 used and what knowledge is used (high agreement) (Nunn, 2013; Prance, 2015; Charan et al., 2017; Nalau et 26 al., 2018a; Parsons et al., 2018; McGinn and Solofa, 2020). | 2709 - 270 | Prot-Adapt-Mitig- | INTANBILE | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 27 28 In Kiribati, communities often use different timescales to evaluate the need for adaptation. I-Kiribati 29 culture's core concept of time is short- and medium term (Prance, 2015), which should be considered in 30 adaptation policy and planning processes especially at the household and community level (Donner and 31 Webber, 2014). Key stakeholders, especially community leaders, should be included and empowered to help 32 design and sustain adaptation (Baldacchino, 2018; Weiler et al., 2018). Focusing on values-as-relations (e.g., 33 island communities' relationship with the environment and each other) could diversify the values considered 34 in adaptation decision-making processes (Parsons and Nalau, 2019). Indeed, those Pacific islands with a 35 more island-centric approach to climate adaptation tend to have overall more successful adaptation policies 36 in place (Schwebel, 2017). | 2709 - 270 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | 52 53 Decisions that are optimal for adaptation may not be acceptable in the wider development context within 54 which they operate. In the Pacific region, where 67% of infrastructure is located within 500 metres of 55 coastline and commercial, public and industrial infrastructure are particularly vulnerable due to the location 56 of urban centres (Kumar and Taylor, 2015). Yet the Parliamentary Complex in Samoa was redeveloped at ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 15 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 15-52 Total pages: 107 1 the original site due to cultural and historical factors despite strong evidence of the need to relocate (Hay et 2 al., 2019b). | 2710 - 271 | Prot-Adapt-Mitig- | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 9 10 Tourism system transitions can enable the sector to contribute to climate resilient development pathways 11 through managing climate risks and improving ecological, economic and social outcomes for small islands 12 (medium evidence, high agreement) (Loehr, 2019; Mahadew and Appadoo, 2019; Loehr et al., 2020; Sheller, 13 2020). | 2711 - 271 | Impact | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 29 30 Early research on the response to COVID-19 indicates that existing disaster response mechanisms in the 31 Caribbean islands have assisted in rapid responses to COVID-19 (Hambleton et al., 2020). Many small 32 islands are highly dependent on tourism for their economies and are facing worsening crises associated with 33 climate-related disasters and more recently COVID-19 disruptions of travel (Sheller, 2020). The adaptive 34 capacity and innovations demonstrated by SIDS during COVID-19, moving beyond dependence on 35 'extractive' international tourism, demonstrate the potential benefits of diversified and sustainable 36 economies (and ecologies) for the enhanced resilience of both human and ecological communities (Sheller, 37 2020). | 2711 - 271 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | 18 19 Observed changes – including increases in air and ocean temperatures, increases in storm surges, heavy 20 rainfall events, and possibly more intense tropical cyclones - are already reducing the number and quality of 21 ecosystem services, thereby causing the disruption of human livelihoods, damage to buildings and 22 infrastructure, and loss of economic activities and cultural heritage on small islands. Widespread observed 23 impacts include severe coral reef bleaching events, such as that associated with the 2015–16 El Niño season, 24 the most damaging on record worldwide. Additionally, the 2017 Atlantic hurricane season was unusually 25 characterised by sequential severe tropical cyclones that resulted in widespread cyclone-induced damage to 26 ecosystems from the very interior of small islands to those of the ocean waters that surround them as well as 27 damage to human settlements and economic activities within the whole Caribbean region. Although 28 knowledge is limited regarding long term increases in tropical cyclone intensity, studies have shown that 29 heavy rainfall and intense wind speed of individual tropical cyclones were increased by climate change. The 30 combination of various climate events, such as tropical cyclones, extreme ocean waves, and El Niño or La 31 Niña phases, with sea-level rise causes increased coastal flooding, especially on low-lying atoll islands of the 32 Indian and Pacific Oceans. | 2712 - 271 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 47 48 The intensity and timing of such impacts will be more severe under high warming futures compared to low 49 warming futures accompanied by ambitious adaptation. Tailored, desirable and locally owned adaptation 50 responses that incorporate both short- and long-term time horizons would certainly help to reduce future 51 risks to nature and human life in small islands. Among the short-term measures frequently employed to 52 address sea-level rise and flooding are seawalls. Long-term measures include ecosystem-based adaptation 53 such as mangrove replanting, relocation of coastal villages to upland sites, creation of elevated land through 54 reclamation, revised building codes as part of a broader disaster risk reduction strategy, shifting to alternative 55 livelihoods and changes in farming and fishing practices. | 2712 - 271 | 'rot-Adapt-Mitig-Impa | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 19 20 Coastal livelihoods in particular are already impacted by climate impacts. Coastal fishers have adapted to 21 these changes in environmental conditions by diversifying livelihoods, expanding aquaculture production, 22 considering weather insurance, building social networks to cope with reduced catches and availability during 23 extreme storms, switching fishing grounds, and changing target species. Similarly, farmers have diversified 24 livelihoods to more cash- and service-based activities such as tourism, changed plant species that thrive 25 better in altered conditions, and shifted planting seasons according to changes in climate. | 2713 - 271 | 'rot-Adapt-Mitig-Impa | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 38 Along small-island coasts, anticipatory adaptation typically involves recognising that sea level will continue 39 rising and that problems currently experienced will be amplified in the future. One strategy for anticipatory 40 adaptation in response to sea level rise and flooding is relocation, which is the movement of coastal 41 communities away from vulnerable (coastal-fringe) locations to sites that are further inland. . Coastal setback 42 policies have been applied to hotels in some islands such as Barbados. In coastal locations where the risks of 43 rising sea level, flooding and erosion are very high and cannot effectively be reduced, 'retreat' from the 44 shoreline is the only way to eliminate or reduce such risks. | 2713 - 271 | 'rot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | 12 13 Ecosystem-based adaptation can be a low-cost anticipatory adaptation measure that is often used in small 14 islands. It is referred to as a 'no-regret' or 'low-regret' strategy because it is low-costing, brings co-benefits 15 and requires less maintenance in contrast to hard engineering structures. Ecosystem-based adaptation is used 16 at different scales and in different sectors such as to protect fisheries, farming and tourism assets, and 17 integrates various stakeholders from national to local governments and non-governmental agencies. Many 18 islands have implemented ecosystem-based adaptation such as watershed management, mangrove replanting 19 and other nature-based solutions to strengthen coastal foreshore areas that are subjected to coastal erosion 20 and flooding caused by sea level rise and changing rainfall patterns. For example, mangroves have been 21 planted on several cays in Belize and pandanus trees have been planted near the coastlines of the Marshall 22 Islands. Agroforestry is another example of ecosystem-based adaptation. Planting trees and shrubs in 23 combination with crops has been used to increase resilience of crops to droughts or excessive rainfall run- 24 off. Case studies show that people living on islands benefit even further from using ecosystem-based 25 adaptation. Their health improves as well as their food and water supply, while risks of disasters caused by 26 extreme events are reduced. | 2714 - 271 | 'rot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | Impacts include inundation of settlements, infrastructure, and tourism facilities as well as coastal erosion. These waves can propagate to and influence reef islands in equatorial areas not usually exposed to high energy waves. | 2720 - 272 | Impact | | |
| IPCC_AR6_WGII_Full_Report | These extraordinary sargassum 'blooms' have resulted in mass deposition of seaweed on beaches throughout the Lesser Antilles, with damage to coastal habitats, mortality of seagrass beds and associated corals, as well as consequences for fisheries and tourism. This recent phenomenon has been linked to climate change as well as the possible influence of nutrients from Amazon River floods and/or Sahara dust. | 2721 - 272 | Impact | | |
| IPCC_AR6_WGII_Full_Report | Of the range of bacterial, fungal and protozoan diseases known to affect stony corals, many have explicit links to temperature. Global projections suggest that disease is as likely to cause coral mortality as bleaching in the coming decades at many localities, with effects occurring earlier at sites in the Caribbean compared to the Pacific and Indian oceans. Model hindcasts suggest that climate�driven changes in sea surface temperature, as well as extreme heatwave events have all played a significant role in the spread of white-band disease throughout the Caribbean. | 2722 - 272 | Impact | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | Key Risks Risk-oriented adaptation options Evidence and agreement Implementation Key enablers Reduction of exposure and vulnerability Co-benefits Disbenefits KR1. Loss of marine and coastal biodiversity and ecosystem services EbA measures (15.4.4) MPAs; paired terrestrial and MPAs Medium evidence, low agreement with regard to climate change adaptation and benefits Widespread across small islands, with climate resilience being a target of some MPAs Strong governance and sufficient financial resources Reduces the ecosystem exposure to human disturbances, increasing their resistance and resilience to climate events For biodiversity, food supply, economics, human health and well�being Active restoration of coastal and marine ecosystems Limited evidence, low agreement with regard to long-term success Mostly small�scale: replanting of mangroves, seagrasses and beach vegetation; transplantation of corals; beach nourishment Funding: adaptation taxes and levies imposed on tourism; blue bonds; public�private partnerships Reduces the vulnerability of natural ecosystems by increasing their resilience Improved water quality; reduction in coastal erosion and flood risks; economic benefits Hard protection (15.5.1) Hard structures designed to enhance marine biodiversity Medium evidence, medium agreement Artificial reefs Funding: adaptation and environmental taxes and levies, with limited evidence of direct reinvestment in conservation and management Uncertainty on reduction of exposure and vulnerability of marine ecosystems; reduces the exposure of population and infrastructure to coastal risks For food supply, economies (tourism), human health and well�being Diversifying livelihoods (15.5.6) Diversifying fisheries livelihoods (e.g. to aquaculture and tourism), Limited to medium evidence, Examples in the Caribbean region and in the Improved governance and cooperation (e.g. | 2724 - 272 | Prot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGII_Full_Report | Maldives) Financial Yes Health; economic (reduced dependence on public supply) Energy intensive (carbon footprint) ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 15 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 15-69 Total pages: 107 Reforestation (15.5.4) Medium evidence, high agreement Examples reported in the Caribbean and Pacific (e.g. Fiji, Papua New Guinea) Governance - whole�of-island approaches foster integrated management practices in small islands Yes, through supporting wetland�oriented tourism Economic (agroforestry); biodiversity (watershed restoration); food security; disaster risk reduction Dependent on mode of implementation. | 2727 - 272 | Impact | | |
| IPCC_AR6_WGII_Full_Report | Hulhumale', Maldives) Technological, financial, institutional, sociocultural, high potential in urban (compared to rural) areas Reduces population exposure where high standard as in Hulhumale', Maldives Offers new land for economic development, generates revenues through sale or lease of land in urban areas Widespread ecosystem destruction, increased negative ACCEPTED impacts of SLR VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 15 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 15-70 Total pages: 107 growth in the Maldives) Migration including planned resettlement (15.5.3) Limited evidence, low agreement with regard to climate change adaptation Village-scale planned resettlement supported by government policy/legislation in the Pacific Participatory inclusion of all social groups; financial (for small and remote communities); social-cultural connections; strong governance frameworks; enabling legislation; land availability or ownership; conditions in receiving locations; technical support Reduced exposure locally; has created new vulnerabilities at some locations by bearing significant economic cost, impacting social capital and reducing access to services New livelihood opportunities Loss of cultural heritage, impacts on receiving communities EbA measures (15.4.4) Medium agreement, medium evidence Increasingly experienced; includes artificial reefs, beach nourishment and vegetation (including mangrove) restoration Environmental/physical conditions; social acceptability; technical capacities (enhanced by external support); funding; inclusion in national adaptation policies Limited evidence to date Biodiversity strengthening; increased food supply; increased human health and well-being KR6. Health degradation Increasing public awareness of health risks associated with climate change; providing training to health sector staff; improving reliability and safety of water storage practices (15.6.2) Limited evidence Few examples Financial and human resources to implement options; early warning and response systems; integrating climate services into health decision-making systems; public uptake and buy in; improving health data collection systems Primarily reduces vulnerability Increased water security ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 15 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 15-71 Total pages: 107 KR7. | 2728 - 273 | Prot-Adapt-Mitig-Impact | | |
| IPCC_AR6_WGII_Full_Report | Limited examples of successful livestock husbandry only in Jamaica Investments in farm inputs Adaptive finance/education (15.5.6) Limited evidence, medium agreement Limited (e.g. in Puerto Rico, women engage in new Tourism income; investment in education and capacity building; Yes, reduces risk and avoids negative Generates opportunities (e.g. | 2730 - 273 | Prot-Adapt-Mitig-Impac | | |

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| IPCC_AR6_WGII_Full_Report | for wetland tourism) ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 15 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 15-72 Total pages: 107 commercial enterprises that do not rely on traditional coffee supply chains or government assistance) working with nature and EbA knock-on effects Product/Market diversification (15.5.6) Diversity of crops, gardening in different areas, storage and preservation of foodstuffs, engagement of women in new commercial enterprises Medium evidence, high agreement Examples in the Caribbean region and Pacific Availability of crops and land, new markets Reduces vulnerability to tropical cyclones in Fiji and Vanuatu; new markets in Puerto Rico Increases food security and improves nutrition; increases income security Adaptation in tourism policies (15.5.6) Limited evidence, high agreement Limited (e.g. in the British Virgin Islands, policies like adaptation taxes and levies imposed on tourism can provide funding for adaptation measures) Tourism regulations and policies that mainstream climate change adaptations; taxes and levies imposed on tourism Limited evidence in reducing vulnerability KR8. Loss of cultural resources and heritage Integrating Indigenous Knowledge and local knowledge (IKLK) with western science to provide integrated approaches to climate change (15.6.5) Medium evidence, high agreement Reported in the Pacific and Caribbean Use of IKLK for preparing for disasters and understanding environmental change; social networks in sharing information and helping others; ecotheology increasing people's awareness of the environment Yes, can reduce vulnerability when IK LK supports robust adaptation; No, can increase vulnerability if IKLK no longer provides Can increase climate change information and its understanding in communities, and increase culturally appropriate climate adaptation Reports from Vanuatu indicates that IK LK are at times inaccurate (eg seasonal calendars, biophysical weather indicators) due to climate ACCEPTED change VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 15 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 15-73 Total pages: 107 accurate information Hard protection (15.5.5.1) Medium agreement, limited evidence with regard to climate change adaptation and success Widespread in protecting cultural sites and villages in both urban and rural areas of the Caribbean, Pacific and Indian Oceans External funding; socio-cultural (generally meets the preference of the population); political�institutional (e.g. | 2730 - 273 | Prot-Adapt-Mitig-Impact | | INDG |
| IPCC_AR6_WGII_Full_Report | (2019) Trotman et al. (2018) SPREP (2016a) Economy and Finance Economic diversification and shifting to CRDPs Tourism system transitions/cooperation from tourism sector Loehr (2019); Mahadew and Appadoo (2019); Loehr et al. (2020); Sheller (2020) Finance models for adaptation Innovative financing models that enable adaptation (e.g., Seychelles) Parametric fisheries insurance products to increase fishery resilience funded by Caribbean Catastrophe Risk Insurance Facility (Grenada and Saint Lucia) Rambarran (2018) CCRIF (2019) Transregional trade agreements/associated pressure Revised socio-political arrangements for better fisheries management (Solomon Islands) Keen et al. (2018) Economic viability via revenue from sale of new land Maldives land raising on Hulhumale "Safe island development programme" after 2004 Indian Ocean Tsunami in the Maldives Bisaro et al. (2019) Shaig (2008) Government subsidies Tuamotu's government subsidy of raised houses Magnan et al. (2018) Co-investments and cooperation between agencies (donors, governments) Tuvalu use of beach nourishment in collaboration with JICA Onaka et al. (2017) Diversification of livelihoods as basis for economic activity Coastal fishers' diversification of livelihoods into the tourism sector (Vanuatu and Madagascar) Blair and Momtaz (2018) ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 15 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 15-75 Total pages: 107 Fishermen varying fishing practices and locations depending on environmental conditions (e.g., Dominican Republic) Karlsson and McLean (2020) Governance Changed governance arrangements resulting in improved coordination Improved governance arrangements: Cross�sectoral and cross-agency coordination (e. g. | 2733 - 273 | Prot-Adapt-Mitig-Impac | | |

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| IPCC_AR6_WGII_Full_Report | A paucity of research exists currently on the vulnerability of island ecosystem services to climate change (Balzan et al., 2018). While there is rich scientific evidence on the pressures of habitat loss and degradation, impacts of natural hazards and invasive species, far less is known about the interactions of these factors with adaptive capacity and livelihood conditions on islands. In small island contexts, there is a specific need for assessing the effectiveness and cost of ecosystem - and community-based solutions where the latter have been implemented (Filho et al., 2020). The design of generic assessment methods and tools is required to allow for comparative analyses that will, in turn, provide useful guidance for the promotion of context�specific adaptation strategies (Blair and Momtaz, 2018). For many of the small islands, especially SIDS, the economic valuation of marine and coastal ecosystem services – coastal protection, fisheries, tourism - is of great importance, as well as the subsequent losses in these sectors and related livelihoods due to climate change impacts (Waite et al., 2014; Schuhmann and Mahon, 2015; World Bank, 2016; Layne, 2017; Duijndam et al., 2020). There are few integrated modelling studies to inform future habitability of differentiated small island types and how these models can inform decision support processes for ridge to reef stewardship (Povak et al., 2020). Existing studies (Rasmussen et al., 2018) have progressed knowledge since AR5, but island-specific analyses are required to robustly estimate the future ability of land to support life and livelihoods, taking into account multiple climate-drivers, future population exposure, and adaptation responses. | 2735 - 273 | rot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGII_Full_Report | 54 55 For most Representative Key Risks (RKRs), potentially global and systemically pervasive risks 56 become severe in the case of high warming, combined with high exposure/vulnerability, low 57 adaptation, or both (high confidence). Under these conditions there would be severe and pervasive risks to ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 16 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 16-6 Total pages: 173 1 critical infrastructure and to human health from heat-related mortality (high confidence), to low-lying coastal 2 areas, aggregate economic output, and livelihoods (all medium confidence), of armed conflict (low 3 confidence), and to various aspects of food security (with different levels of confidence). Severe risks 4 interact through cascading effects, potentially causing amplification of RKRs over the course of this century 5 (low evidence, high agreement). {16.5.2.3, 16.5.2.4, 16.5.4, Figure 16.10} 6 For some RKRs, potentially global and systemically pervasive risks would become severe even with 7 medium to low warming (i.e. 1.5-2°C) if exposure/vulnerability is high and/or adaptation is low 8 (medium to high confidence). Under these conditions there would be severe and pervasive risks associated 9 with water scarcity and water-related disasters (high confidence), poverty, involuntary mobility, and insular 10 ecosystems and biodiversity hotspots (all medium confidence). {16.5.2.3, 16.5.2.4} 11 12 All potentially severe risks that apply to particular sectors or groups of people at more specific 13 regional and local levels require high exposure/vulnerability or low adaptation (or both), but do not 14 necessarily require high warming (high confidence). Under these conditions there would be severe, 15 specific risks to low-lying coastal systems, to people and economies from critical infrastructure disruption, 16 economic output in developing countries, livelihoods in climate-sensitive sectors, waterborne diseases 17 especially in children in low- and middle-income countries, water-related impacts on traditional ways of life, 18 and involuntary mobility for example in small islands and low-lying coastal areas (medium to high 19 confidence). {16.5.2.3, 16.5.2.4} 20 21 Some severe impacts are already occurring (high confidence) and will occur in many more systems 22 before mid-century (medium confidence). Tropical and polar low-lying coastal human communities are 23 experiencing severe impacts today (high confidence), and abrupt ecological changes resulting from mass 24 population-level mortality are already observed following climate extreme events. Some systems will 25 experience severe risks before the end of the century (medium confidence), for example critical infrastructure 26 affected by extreme events (medium confidence). Food security for millions of people, particularly low- 27 income populations, also faces significant risks with moderate to high warming or high vulnerability, with a 28 growing challenge by 2050 in terms of providing nutritious and affordable diets (high confidence). {16.5.2.3, 29 16.5.3} 30 31 In specific systems already marked by high exposure and vulnerability, high adaptation efforts will 32 not be sufficient to prevent severe risks from occurring under high warming (low evidence, medium 33 agreement). This is particularly the case for some ecosystems and water-related risks (from water scarcity 34 and to indigenous and traditional cultures and ways of life). {16.5.2.3, 16.5.2.4, 16.5.3} 35 36 Interconnectedness and globalization establish pathways for the transmission of climate-related risks 37 across sectors and borders, for instance through trade, finance, food, and ecosystems (high 38 confidence). Examples include semiconductors, global investments, major food crops like wheat, maize and 39 soybean, and transboundary fish stocks. There are | 2771 - 277 | rot-Adapt-Mitig-Impac | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 11 12 RFC1, RFC2 and RFC5 include risks that are irreversible, such as species extinction, coral reef degradation, 13 loss of cultural heritage, or loss of a small island due to sea level rise. Once such risks materialise, as is 14 expected at very high risk levels, the impacts would persist even if global temperatures would subsequently 15 decline to levels associated with lower levels of risk in an 'overshooting' scenario (high confidence). | 2774 - 277 | Impact | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 12 13 16.2.3.7 Vector-borne Diseases 14 15 Vector-borne diseases constitute a large burden of infectious diseases worldwide and are highly sensitive to 16 fluctuations of weather conditions including extreme events. Thus, both extreme rainfall and droughts have 17 increased infections (high confidence, see documentation of cases in 'Other societal impacts - Vector-borne 18 diseases', Table SM16.23). For example, in Sudan, anomalous high rainfall increased Anopheles mosquito 19 breeding sites, leading to malaria outbreaks (Elsanousi et al., 2018) while in Barbados and Brazil, drought 20 conditions in urban areas have enhanced dengue incidence due to changes in water storage behaviour 21 creating breeding sites for Aedes mosquitoes around human dwellings (Lowe et al., 2018; Lowe et al., 22 2021)). In the Caribbean and Pacific island nations, weather extremes, such as storms and flooding have led 23 to outbreaks of dengue due to disruption to water and sanitation services, leading to increased exposure to 24 Aedes mosquito breeding sites (Descloux et al., 2012; Sharp et al., 2014; Uwishema et al., 2021). In South 25 and Central America, and Asia, dengue incidence has been shown to sensitive to variations in temperature 26 and the monsoon season in addition to variations induced by urbanization and population mobility (high 27 confidence (South and Central America); medium confidence (Asia); see 'Other societal impacts - Vector- 28 borne diseases', Table SM16.23). | 2787 - 278 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 22 Engagement by sub-national governments in adaptation is more frequently documented in Europe and North 23 America (Craft and Howlett, 2013; Craft et al., 2013; Bauer and Steurer, 2014; Lesnikowski et al., 2015; Shi 24 et al., 2015; Austin et al., 2016). Reporting of private sector engagement is generally low. Civil society 25 participation in adaptations is reported across all regions. Consistent with this, local governments are also 26 widely reported in documented adaptation responses, particularly where municipal jurisdiction is high, 27 including cities, infrastructure, water, and sanitation. | 2794 - 279 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | 30 31 The mix of adaptation response types differs across regions and sectors. Technological and infrastructural 32 responses are widely reported in Europe, and globally in the context of cities and water and sanitation (Mees, 33 2017; Hintz et al., 2018). Responses to flood risk in Europe include the use of flood and climate resistant 34 building materials, large scale flood management, and water storage and irrigation systems (van Hooff et al., 35 2015; Mees, 2017). Technological and infrastructural responses are also documented to some extent in 36 agriculture, including for example breeding more climate resilient crops, precision farming and other high- 37 tech solutions such as genetic modification (Makhado et al., 2014; Fisher et al., 2015; Costantini et al., 2020; 38 Fraga et al., 2021; Grusson et al., 2021; Naulleau et al., 2021). While less common, institutional responses 39 are more prominent in North America and Australasia as compared to other regions, and include zoning 40 regulations, new building codes, new insurance schemes, and coordination mechanisms (Craft and Howlett, 41 2013; Craft et al., 2013; Parry, 2014; Ford et al., 2015b; Beiler et al., 2016; Lesnikowski et al., 2016; Labbe 42 et al., 2017; Sterle and Singletary, 2017; Hu et al., 2018; Conevska et al., 2019). Institutional adaptations are 43 more frequently reported in cites than other sectors. Institutional adaptation may be particularly subject to 44 reporting bias, however, with many institutional responses likely to be reported in the grey literature (see 45 Chapter 17). Nature-based solutions are less frequently reported, except in Africa, where they are relatively 46 well-documented, and in the content of terrestrial systems where reports included species regeneration ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 16 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 16-30 Total pages: 173 1 projects, wind breaks, erosion control, reforestation, and riparian zone management (Munji et al., 2014; 2 Partey et al., 2017; Muthee et al., 2018). | 2795 - 279 | Prot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | (2019) Storage of large quantities of water in the home Water rendered unsafe for drinking due contamination by fecal coliforms in Zimbabwe; drought-induced changes in water harvesting and storage increased breeding sites for mosquitoes (Australia); Water storage facilities and tanks provided ideal breeding conditions for mosquitoes and flies bringing both vectors and diseases closer to people (Ethiopia). | 2801 - 2801 | | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII _Full_Report | (2014);Wiederkehr et al. (2018); Yegbemey et al. (2017); Yila and Resurreccion (2013); Nizami et al. (2019); Mersha and Van Laerhoven (2016); Ojha et al. (2014); Radel et al. (2018); Gioli et al. (2014); Hooli (2016); Koubi et al. (2016) ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 16 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 16-37 Total pages: 173 Certain autonomous, forced, and planned relocation Temporary resettlement (India) Expansion of informal settlements in cities (Solomon Islands); relocation to areas prone to landslide and soil erosion or insufficient housing (Fiji); disproportionate burden on vulnerable communities (China); temporary relocation created gender inequality associated with minimal privacy; poor access to private toilets; sexual harassment; reduced sleep; insufficient or food rationing; exploitation and abuse of children (India); inadequate funding and governance mechanism for community-based relocation caused loss of culture, economic decline and health concerns (Alaska); relocation of supply chain to reduce exposure to climate change resulted in adverse outcomes for communities along the supply chain. | 2802 - 2803 | | | |
| IPCC_AR6_WGII _Full_Report | (2019) Return to traditional farming practices Mitigation, especially carbon sequestration Pienkowski and Zbaraszewski (2019) Place-specific practices & innovations: animal cross-breeding; direct crop seeding; site�specific nutrient management; irrigation innovations; use of riparian buffer strips; Mitigation, especially carbon sequestration; improved crop yields; food security Sushant (2013); Balaji et al. (2015); Helling et al. (2015); Jorgensen and Termansen (2016); Sen and Bond (2017); Wilkes et al. | 2803 - 280 | Prot-Adapt-Mitig- | INTANBILE | |
| IPCC_AR6_WGII _Full_Report | (2020) ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 16 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 16-38 Total pages: 173 use of green winter land; rice-rice system Land and water management Agroforestry Mitigation, especially carbon sequestration; biodiversity and ecosystem conservation; improved food security; plant species diversification; diversification of household livelihoods; improved household incomes; improved access to forage material; energy access and reduced fuel wood gathering time and distance for women; soil and water conservation; aesthetic improvements in landscapes Holler (2014); Suckall et al. (2015); Sharma et al. (2016); Nyasimi et al. (2017); Pandey et al. (2017); Schembergue et al. (2017); Ticktin et al. (2018); Debray et al. (2019); Jezeer et al. (2019); Krishnamurthy et al. (2019); Nyantakyi-Frimpong et al. (2019); Tschora and Cherubini (2020) Afforestation and reforestation programs; Forest management practices (e.g., tree thinning) Mitigation, especially carbon sequestration; biodiversity and ecosystem conservation; new employment opportunities; diversification of household livelihoods; increased household incomes; improved access to fuel wood; harvesting opportunities from enclosures Holler (2014); Etongo et al. (2015); Diederichs and Roberts (2016); Acevedo�Osorio et al. (2017); Nyasimi et al. (2017); Krishnamurthy et al. (2019); Rahman et al. | 2803 - 280 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII _Full_Report | 25 26 16.4.2.1 Small Island Developing States (SIDS) 27 28 An expanding volume of empirical research highlights existing adaptation constraints that may lead to soft 29 limits in SIDS. Investigation of national communications among 19 SIDS found that financial constraints, 30 institutional challenges and poor resource endowments were the most-frequently reported as inhibiting 31 adaptation for a range of climate impacts (Robinson, 2018b). Governance, financial and information 32 constraints such as unclear property rights and lack of donor flexibility have led to hasty implementation of 33 adaptation projects in Kiribati, whereas in Vanuatu and the Solomon Islands, limited awareness of rural 34 adaptation needs and weak linkages between central governance and local communities have resulted in an 35 urban bias in resource allocation (Kuruppu and Willie, 2015). Limited availability and use of information 36 and technology also present constraints to adaptation – many SIDS suffer from lack of data and established 37 routines to identify loss and damage, and the combination of poor monitoring of slow-onset changes and 38 influence of non-climatic determinants of observed impacts challenges attribution (Thomas and Benjamin, 39 2018). The fact that climate information is often available only in the English language represents another 40 common constraint for island communities (Betzold, 2015). Although indigenous and local knowledge 41 systems can provide important experience-based input to adaptation policies (Miyan et al., 2017), socio- 42 cultural values and traditions such as attachment to place, religious beliefs and traditions can also constrain 43 adaptation in island communities, particularly for more transformational forms of adaptation (Ha'apio et al., 44 2018; Oakes, 2019). | 2812 - 281 | 'rot-Adapt-Mitig-Impac | INTANBILE | INDG |
| IPCC_AR6_WGII _Full_Report | 12 13 Residual risks for SIDS include loss of marine and terrestrial biodiversity and ecosystem services, increased 14 food and water insecurity, destruction of settlements and infrastructure, loss of cultural resources and 15 heritage, collapse of economies and livelihoods and reduced habitability of islands (Section 3.5.1, Section 16 15.3). | 2813 - 281 | Impact | | |

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| IPCC_AR6_WGII_Full_Report | 47 48 Residual risks associated with livelihoods in Africa include poorer households becoming trapped in cycles of 49 poverty (Section 9.9.3), increased rates of rural-urban migration (Section 9.8.4), decline of traditional 50 livelihoods such as in agriculture (Section 9.9.3, Section 9.11.3.1) and fisheries (Section 9.11.1.2) and loss of 51 traditional practices and cultural heritage (Section 9.9.2). | 2814 - 281 | Impact | | |
| IPCC_AR6_WGII_Full_Report | Actor/system at risk Adaptation limits Residual risks Terrestrial species in islands at risk to loss of habitat Hard: autonomous adaptation unable to overcome loss of habitat and lack of physical space (***) (Box CCP1.1) Biodiversity decline, local extinctions, half of all species currently considered to be at risk of extinction occur on islands (Box CCP 1.1) Terrestrial species across Africa at risk to habitat changes Hard: beyond 2°C many species will lack suitable climate conditions by 2100 despite migration and dispersal (***) (9.6.4.1) 9% of species face complete range loss (*) mountain-top endemics and species at poleward boundaries of African continent at risk of range loss due to disappearing cold climates (***) (9.6.4.1) African aquatic organisms at risk to habitat changes Hard: thermal changes above optimal physiological limits will reduce available habitats (9.6.2.4) Greater risks of loss of endemic fish species than generalist fish species (9.6.2.4) African coastal and marine ecosystems at risk to habitat changes Hard: at 2°C bleaching of east African coral reefs (***) (9.6.2.3) Over 90% of east African coral reefs destroyed at 2C (***) (9.6.2.3) Coral reefs at risk to oceanic changes Hard: coral restoration and management no longer effective after 2°C (***), enhanced coal and reef shading no longer effective after 3°C (**) (Figure 3.23) Loss of more than 80% of healthy coral cover, loss of livelihoods dependent on coral reefs (***) (Figure 3.23, Table 8.7) Cold-adapted species whose habitats are restricted to polar and high mountaintop areas at risk to loss of climate space Hard: evolutionary responses unable to keep pace with the rate of climate change and degraded state of ecosystems (2.6.1, CCP 1.2.4.2) Species extinctions in the case of species losing its climate space entirely on a regional or global scale (2.6.1, CCP 1.2.4.2) Ecosystems in North America at risk to multiple climate hazards Soft: governance constraints hinder implementation of adaptation strategies Hard: some species unable to adapt (Table 14.8) - Ecosystems and species at risk to multiple climate hazards Soft: financial and knowledge constraints lead to limits for interventionist approaches such as translocation of species or ecosystem restoration Hard: some habitats unable to be effectively restored (2.6.6) Species extinctions and changes, irreversible major biome shifts (2.6.6) Coastal settlements in Australia and New Zealand at risk to sea level rise Soft and hard: limits in the efficacy of coastal protection and accommodation approaches as sea levels rise and extreme events intensify (Box 11.5) With 1-1.1m of sea level rise, value of coastal urban infrastructure at risk in Australia is A$164 to >226 billion while in NZ it is NZ$43 billion. Sea level rise will also result in significant cultural and archaeological sites disturbed and increasing flood risk and water insecurity with health and well-being impacts on Australia's small northern islands (Box 11.5) ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 16 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 16-51 Total pages: 173 Human settlements in coastal areas in the 1 in 100 year floodplain at risk to coastal flooding Soft: socio-economic, institutional and financial constraints may lead to soft limits well in advance of technical limits of hard engineering measures (CCP 2.3.2, 2.3.4) Hard: Nature based measures (e.g. | 2816 - 281 | 'rot-Adapt-Mitig-Impa | INTANBILE | |

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| IPCC_AR6_WGII_Full_Report | Retreat strategies reach hard limits as availability and affordability of land decreases (CCP 2.3.2.3, CCP 2.3.5) at 3°C, globally up to 510 million people and up to US$12,739 billion in assets at risk by 2100 (CCP 2.2.1) Communities in small islands at risk to freshwater shortages Hard: domestic freshwater resources unable to recover from increased drought, sea level rise and decreased precipitation by 2030 (RCP8.5+ ice-sheet collapse), 2040 (RCP8.5) or 2060 (RCP4.5) (Box 4.2, 4.7.2) Migration of communities due to water shortages with impacts on well-being, community cohesion, livelihoods and people-land relationships (Box 4.2) Communities in North America at risk to poor water quality Soft: financial and technological constraints lead to limits in ability to treat water for harmful algal blooms. (Table 14.8) Communities in Western and Central Europe at risk to water shortages Hard: at 3°C, geophysical and technological limits reached in Southern Europe (13.10.3.3) At 3°C, two thirds of the population of Southern Europe at risk to water security with significant economic losses in water and energy dependent sectors (**) (13.2.2, 13.6, 13.10.2.3) Communities in Central and South America at risk to water shortages Soft: improved water management as an adaptation strategy unable to overcome lack of trust and stakeholder flexibility, unequal power relations and reduced social learning. (12.5.3.4) Increasing competition and conflict associated with high economic losses (**); glacier shrinkage leading to loss of related livelihoods and cultural values (12.5.3.1, Table 8.7) Agricultural production in Europe at risk to heat and drought Soft: above 3°C, unavailability of water will limit irrigation as an adaptation response (***) (13.5.1, 13.10.2.2) At 3-4°C, yield losses for maize may reach up to 50% (**) (13.5.1, 13.10.2.2) Crops at risk to temperature increase Soft: socio-economic and political constraints limit uptake of climate-resilient crops (5.4.4.3) Hard: after 2°C, cultivar changes unable to offset global production losses (5.4.4.1) Costs of adaptation and residual damages are US$63 billion at 1.5°C. US$80 billion at 2°C and US$128 billion at 3°C, with greater risks and damages in tropical and arid regions (5.4.4.1) Human health in Europe at risk to heat Soft: many adaptation measures will not be able to fully mitigate overheating in buildings with high levels of global warming (***) (13.6.2.3) Hard: above 3°C, people and health systems unable to adapt (***) (13.6.2.3, 13.7.2, 13.7.4, 13.10.2.1, 13.8) At 1.5°C, 30,000 annual deaths due to extreme heat with up to 90,000 annual deaths at 3C in 2100 (***) (13.7.1) At 3°C, thermal comfort hours during summer will decrease by as much as 74% in locations in southern Europe (***) (13.6.1.5) Human health at risk to heat Soft: socio-economic constraints limit adaptation responses to extreme heat (7.4.2.6, Table 8.7) Globally the impact of projected climate change on temperature�related mortality is expected to be a net increase under RCP4.5 to RCP8.5, even with adaptation, particularly for regions with warm climates (****) (7.3.1, Table 8.7) South Asian settlements at risk to coastal flooding, drought, sea level rise and heatwaves Soft and hard: At 4.5ºC, maximum temperature is expected to exceed survivability threshold across most of South Asia, particularly relevant for outdoor work (*) (Table 10.6) At RCP4.5, 25-50% of population affected; at RCP8.5 more than 50% of population affected. At 4.5ºC of warming, increase in heat-related deaths of 12.7% in South Asia (*) (Table 10.6) ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 16 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 16-52 Total pages: 173 Tourism in Europe reliant on snow at risk to higher levels of warming Soft: at 3°C, snowmaking as an adaptation measure limited by biophysical and financial | 2817 - 281 | 'rot-Adapt-Mitig-Impa | INTANBILE | |
| IPCC_AR6_WGII Full Report | Social/cultural constraints (social status, caste and gender) also affect adaptation in contexts with deep-rooted traditions (Section 9.12.4). | 2819 - 281 | Prot-Adapt-Mitig- | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 25 Impacts on agriculture and food prices could force between 3 to 16 million people into extreme poverty 26 (Hallegatte and Rozenberg, 2017). Within-country inequality is expected to increase following extreme 27 weather events (Section 16.2.3.6 and Chapter 8). Households affected by climate-related extreme events may 28 be faced with continuous reconstruction efforts following extreme events (Adelekan and Fregene, 2015) or 29 declines in critical livelihood resources in the agriculture, fisheries and tourism sectors (Forster et al., 2014, 30 Section 3.5.1). Further erosion of livelihood security of vulnerable households creates the risk of poverty 31 traps, particularly for rural and urban landless (Section 8.2.1, Section 8.3.3.1), for example in Malawi and 32 Ethiopia (Section 9.9.3). Levels of labour productivity and economic outputs are projected to decrease as 33 temperatures rise particularly in urban areas (Section 6.2.3.1). At the same time, higher utilities demand 34 under higher urban temperatures exert additional economic stresses on urban residents and households. | 2821 - 282 | Impact | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 22 23 KRs are determined not just by the nature of hazards, exposure, vulnerability, and response options, but also 24 by values, which determine the importance of a risk. Importance is understood here as the degree of 25 relevance to interpreting DAI at a given system's level or scale, and was an explicit criterion for identifying 26 key vulnerabilities and risks in AR5 (Oppenheimer et al., 2014). Because values can vary across individuals, 27 communities, or cultures, as well as over time, what constitutes a KR can vary widely from the perspective 28 of each of these groups, or across individuals. For example, ecosystems providing indirect services and 29 cultural assets such as historic buildings and archaeological sites may be considered very important to 30 preserve by some people but not by others; and some types of infrastructure, such as a commuter rail, may be 31 important to the well-being of some households but less so to others. Therefore, Chapter 16 authors do not 32 make their own judgements about the importance of particular risks. Instead, we highlight importance as an 33 overarching factor but identify and evaluate KRs based on four other criteria for what may be considered 34 potentially severe. | 2822 - 282 | Impact | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 44 45 Many KRs are especially prominent in particular regions or systems, or for particular subgroups of the 46 population. For example, coastal systems and small islands are a nexus of many KRs, including those to 47 ecosystems and their services, especially coral reefs; people (health, livelihoods); and assets, including 48 infrastructure. Risks to socio-ecological systems in polar regions are also identified as KRs, as are ecological 49 risks to the Amazon forest in South America and savannahs in Africa. For some regions risks from wildfire 50 are of particular concern, including in Australasia and North America. Vector-borne diseases are a particular 51 concern in Africa and Asia. Loss of cultural heritage is identified as a KR in Small Islands, Mountain 52 Regions, Africa, Australasia, and North America. | 2823 - 282 | Impact | | |
| IPCC_AR6_WGII_Full_Report | Overlaps with key risk (v) 16.5.2.3.6 RKR-G Risk to water security Risk from water related hazards (floods and droughts) and water quality deterioration. Focus on water scarcity, water-related disasters and risk to indigenous and traditional cultures and ways of life Overlaps with key risk (iv) 16.5.2.3.7 RKR-H Risks to peace and to human mobility Risks to peace within and among societies from armed conflict as well as risks to low-agency human mobility within and across state borders, including the potential for involuntarily immobile populations. | 2825 - 282 | Impact | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 5 6 16.5.2.3.1 Risk to the integrity of low-lying coastal socio-ecological systems (RKR-A) 7 RKR-A considers climate change-related risks to low-lying coasts including their physical, ecological and 8 human components. Low-lying systems are those occupying land below 10 m of elevation that is contiguous 9 and hydrologically connected to the sea (McGranahan et al., 2007). The assessment builds on Key Risks 10 identified in chapters 3 and 15, Cross Chapter Paper 2 as well as in the SROCC (Magnan et al., 2019; 11 Oppenheimer et al., 2019). It highlights risks to (i) natural coastal protection and habitats; (ii) lives, 12 livelihoods, culture and well-being; and (iii) critical physical infrastructure; it therefore overlaps with several 13 other RKRs (Fig. 16.10 and 16.11) but within a coastal focus. It encompasses all latitudes and considers 14 multiple sources of climate hazards, including sea-level rise (SLR), ocean warming and acidification, 15 permafrost thaw, and sea-ice loss and changes in weather extremes. | 2826 - 282 | 'rot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGII_Full_Report | 16 17 Severe risks to low-lying coasts involve irreversible long-term loss of land, critical ecosystem services, 18 livelihoods, well-being or culture in relation to increasing combined drivers, including climate hazards and 19 exposure and vulnerability conditions. The definition depends on the local context because of variation in the 20 perception of tolerable risks and the limits to adaptation (Handmer and Nalau, 2019). Accordingly, a 21 qualitative range of consequences is presented here, in place of a quantitative global severe risk threshold. | 2826 - 282 | 'rot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGII_Full_Report | 8 9 (ii) Impacts to lives, livelihoods, culture and well-being — In the absence of effective adaptation, changing 10 extreme and slow-onset hazards combined with anthropogenic drivers (e.g., increased population pressure at 11 the coast between +5% and +13.6% by 2100 compared to today, Jones and O'Neill, 2016) will lead to loss of 12 lives, livelihoods, health, well-being, and/or culture (McGregor et al., 2016; Pinnegar et al., 2019; Pugatch, 13 2019; Schneider and Asch, 2020; Thomas and Benjamin, 2020; McNamara et al., 2021) (high confidence). | 2827 - 282 | 'rot-Adapt-Mitig-Impac | | |

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| IPCC_AR6_WGII_Full_Report | 14 Catastrophic examples that may foreshadow the future include Hurricane Sandy in 2012 (Strauss et al., 15 2021)and super Typhoon Haiyan in 2013 (>6,000 deaths and inequities in access to safe housing; Trenberth 16 et al. 2015) (6.2.2, 6.3.5.1). Although there is no unique definition of ‘intolerable’ loss, risks are generally 17 expected to become severe over this century (Tschakert et al., 2017; Dannenberg et al., 2019; Tschakert et 18 al., 2019). Globally, with High warming, 90 to 380 million more people will be exposed to annual flood 19 levels by the mid- and end-century, respectively, compared to 250 million people today (Kulp and Strauss, 20 2019; Kirezci et al., 2020), with potential implications on forced displacement or migration (Oppenheimer et 21 al., 2019; Wrathall et al., 2019; Hauer et al., 2020; Lincke and Hinkel, 2021, Section 16.5.2.3.9). Some of the 22 largest fish-producing and fish-dependent ecoregions have already experienced losses of up to 35% in 23 marine fisheries productivity due to warming (Free et al., 2019), and about 11% of the global population will 24 face increasing nutritional risks if current trajectories continue (Golden et al., 2016). While difficult to 25 measure, current climate-driven losses to (indigenous) knowledge, traditions (Tschakert et al., 2019; Pearson 26 et al., 2021) and well-being (Ebi et al., 2017; Cunsolo and Ellis, 2018; Jaakkola et al., 2018) indicate such 27 risk as already severe in some regions (low evidence, medium agreement), jeopardizing communities’ 28 realization of their rights to food, health and culture. In the Arctic, climate-driven changes to ice and weather 29 regimes have substantially affected traditional coastal-based hunting and fishing activities (Fawcett et al., 30 2018; Galappaththi et al., 2019; Huntington et al., 2020; Nuttall, 2020, CCP6), and where permafrost thaw, 31 SLR and coastal erosion are contributing to threatening cultural sites (Hollesen et al., 2018; Fenger-Nielsen 32 et al., 2020). | 2827 - 282 | Impact | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 8 Transport and energy infrastructure in coasts, polar systems and along rivers are projected to face a 9 particularly steep rise in risk, resulting in severe risk even under medium warming (high confidence). Risk in 10 relation to the increasing intensity and frequency of extreme events might become severe before the middle 11 of the century (medium confidence). Damages from multiple climate hazards to transport, energy, industry 12 and social infrastructure in Europe could increase tenfold by the 2080s, from 3.4 € billion annually to date, 13 and 15-fold for transport infrastructure, under Medium warming (A1B, ~3°C by 2100) and with current 14 adaptation levels, even if no further extension of the infrastructure in exposed areas is considered (Forzieri et 15 al., 2018). Under High warming (RCP8.5) in 2100, the percent of roads in the United States that require 16 rehabilitation due to high temperatures and precipitation is expected to increase to 23–33%, relative to 14% 17 in 2100 when no climate change is considered (Mallick et al., 2018). Projections of climate-induced changes 18 in exposure are an incomplete measure of risk but in the absence of other metrics can serve as a proxy for the 19 potential for severe impacts. In the circumpolar Arctic, 14.8% of critical infrastructure assets would be 20 affected by climate change under RCP8.5 by 2050, with lifecycle replacement costs projected to increase by 21 27.7% if infrastructure is to be preserved at current adaptation levels (Suter et al., 2019). Under RCP8.5, the 22 number of ports under high risk will increase from 3.8% in the present day to 14.4% by 2100, as a result of 23 increased coastal flooding and overtopping due to sea level rise, as well as the heat stress impacts of higher 24 temperatures (Izaguirre et al., 2021). In the UK under High warming (4ºC), the number of clean and 25 wastewater treatment sites located in the 1 in 75-year floodplain will increase by a third relative to today by 26 the 2080s under current vulnerability and adaptation levels (Dawson et al., 2018). A global assessment of 27 changing climate and water resources for electricity generation finds considerable reductions in usable 28 hydropower and thermoelectric capacity by 2050 for a range of warming scenarios from Low to High, with 29 absolute declines on average for most (61–74%) of the world’s hydropower resources and monthly 30 maximum reductions above 30% of usable capacity for over two-thirds of 1,427 thermoelectric power plants 31 worldwide (Van Vliet et al., 2016). Many studies find large technical potential for coordinated adaptation- 32 mitigation policies in the electricity sector to avoid a significant portion of projected climate change impacts 33 (e.g., a two-thirds reduction, and in some cases fully offset) (Ciscar and Dowling, 2014; Van Vliet et al., 34 2016; Gerlak et al., 2018; Allen-Dumas et al., 2019). | 2830 - 283 | 'rot-Adapt-Mitig-Impa | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 3 4 16.5.2.3.7 Risk to water security (RKR-G) 5 Water security encompasses multiple dimensions: water for sanitation and hygiene, food production, 6 economic activities, ecosystems, water-induced disasters, and use of water for cultural purposes (Chapter 4; 7 Box 4.1; Section 4.6.1). Water security risks are a combination of water-related hazards such as floods, 8 droughts, and water quality deterioration, and exposure of vulnerable groups exposed to too little, too much, 9 or contaminated water. Reasons for these can include both environmental conditions and issues of safety and 10 access influenced by effectiveness of water governance (Sadoff et al., 2020). These are manifest through loss 11 of lives, property, livelihoods and culture, and impacts on human health and nutrition, ecosystems and water- 12 related conflicts which in turn can drive forced human displacement. | 2836 - 283 | Impact | INTANBILE | |

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| IPCC_AR6_WGII_Full_Report | 13 14 This RKR focuses on three types of risks with the potential to become severe: those associated with water 15 scarcity, those driven by water-related disasters, and those impacting indigenous and traditional cultures and 16 ways of life. Risk to water security constitutes a potentially severe risk because climate change could impact 17 the hydrologic cycle in ways that would lead to substantial consequences for the health, livelihoods, 18 property, and cultures of large numbers of people. For those associated with water scarcity, 'severe' refers to 19 magnitude (number of people in areas where water scarcity falls below recognised thresholds for adequate 20 water supply per capita), along with the likelihood of unforeseen increases in water scarcity that outpace the 21 ability to prepare for the increased risk by putting in place new large-scale infrastructure within the required 22 timescale. For those associated with extreme events, 'severe' refers to magnitude (numbers of people 23 affected, including deaths, physical health impacts including disease, mental health impacts, loss of 24 livelihoods, loss of or damage to property) and timing (for example, events coinciding with other stresses, 25 e.g., a pandemic occurring at a time when local infrastructures are weakened by an extreme weather event). | 2836 - 283 | Impact | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 26 Important water-related extreme events include river flooding caused by heavy and/or prolonged rainfall, 27 glacial lake outburst floods, and droughts. For those impacting cultures, 'severe' refers to the loss of key 28 aspects of traditional ways of life. This includes consequences of the above two key risks. | 2836 - 283 | Impact | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 31 32 Risks to cultural uses of water can become severe if there are permanent loss of aspects of communities' 33 cultures due to changes in water, including loss of areas of ice or snow with spiritual meanings, loss of 34 culturally-important places of access to such places, and loss of culturally-important subsistence practices 35 including by indigenous people (Chapter 4). This includes mountain regions where changes in the 36 cryosphere are having profound impacts (CCP5). In these cases, severe outcomes would be defined locally 37 rather than globally. Communities that lost a dominant environmental characteristic deeply associated with 38 its cultural identity would be considered to be severely impacted. For example, due to the central role that 39 travel on sea ice plays in the life of Inuit communities, providing freedom and mental wellbeing, loss of sea 40 ice can be argued to represent environmental dispossession of these communities (Durkalec et al., 2015). | 2837 - 283 | Impact | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 50 51 There is strong potential for increases in water scarcity, flooding, loss of snow and ice and changes in water 52 bodies to lead to severe outcomes such as deaths from water-related diseases, drowning and starvation, long- 53 term health impacts arising from malnutrition and diseases, loss of property, loss of existence or access to 54 places of cultural significance, loss of livelihoods and loss of aspects of culture especially for indigenous 55 people with traditional lifestyles. The numbers of people affected are projected to range from hundreds of 56 millions to several billion, depending on the level of global warming and socio-economic futures. A key 57 aspect of the risk is the high uncertainty in future regional precipitation changes in many regions of high ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 16 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 16-72 Total pages: 173 1 vulnerability, including the potential for large and highly-impactful changes, for which it may not be 2 possible to provide adaptation measures before they become needed, leading to a high likelihood of 3 adaptation deficits. | 2837 - 283 | ʼrot-Adapt-Mitig-Impac | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 53 In AR6, moderate risks have already been assessed to have occurred in Africa for economic growth and 54 reduced inequality, biodiversity and ecosystems, mortality and morbidity due to heat extremes and infectious 55 disease, and food production in fisheries and crop production (Figure 9.6). In Europe moderate risks to heat 56 stress, mortality and morbidity have already been reached, as well as for water scarcity in some regions 57 (Figure 13.30, Figure 13.33). In Australasia, moderate risks are assessed as present already for heat related ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 16 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 16-107 Total pages: 173 1 mortality risk as well as cascading effects on cities and settlements; and also very high risks already present 2 in coral reef systems, and high risks to kelp forests and alpine biodiversity (Figure 11.7). In North America, 3 moderate risks have already been reached for freshwater scarcity, water quality (Figure 14.4), agriculture, 4 forestry, tourism, transport, energy & mining and construction (Figure 14.10). | 2872 - 287 | Impact | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 39 40 High risks to crop production are assessed to occur in Africa ~1.5-2ºC warming (Figure 9.6), to agriculture 41 in North America for ~1.5ºC warming (Figure 14.10), and ~ 2.8ºC Europe (Figure 13.30). High risks of 42 mortality and morbidity due to heat extremes and infectious disease are assessed to be reached in Africa with 43 ~1.5ºC warming (Figure 9.6); heat stress, mortality and morbidity in Europe is assessed to reach a high level 44 of risk at ~2ºC (Figure 13.30). Heat related mortality risk transitions to a high level by ~1.5-2ºC warming in 45 Australasia while cascading effects on cities reach high risk with ~1.2ºC warming (Figure 11.7). Risks to 46 water scarcity, forestry, tourism and transportation in N America are projected to reach high levels with ~2ºC 47 warming (Figure 14.4, Figure 14.10). | 2873 - 287 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 9 10 [END BOX 17.2 HERE] 11 12 13 17.2.2.3 Adaptation Beyond Risk: Exploiting Opportunities 14 15 Several studies and many government planning documents reference how people can benefit from a changed 16 climate, beyond reducing risks. For example, several regions are expecting an increase in visitors to eco- 17 tourism sites or national parks with a changing climate (Fisichelli NA, 2015; Lwasa, 2015). In Europe, 18 several national adaptation plans include planning for potential benefits of a changing climate, including 19 reduced winter mortality and improved conditions for hydropower (Biesbroek et al., 2010). Recognizing the 20 need for economic diversification, people working in certain industries, such as coastal management, 21 perceive climate change as a factor increasing the need for their services (Fatorić et al., 2017). Northern 22 countries are taking advantage of ice-free waters for shipping routes in the Arctic (Eguiluz et al., 2016; Melia 23 et al., 2016; IPCC, 2019e-a). In Africa, opportunistic adaptation has been observed by smallholder farmers, 24 who plant crops that are better suited for a changing climate (Lalou et al., 2019). Similar agricultural 25 adaptation in Pakistan has been associated with improved food security and reduced poverty (Ali and 26 Erenstein, 2017; Rahman et al., 2020). In each of these cases documenting benefits, there are also potential 27 negative impacts on other populations or ecosystems, such as ecosystem impacts from increased Arctic 28 shipping (Ng et al., 2018). | 2963 - 296 | 'rot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | 30 Some behavioural adaptations, such as changing diets and reducing food waste, can also require large 31 transformations in land use and food culture (medium confidence). Spatial planning, including urban zoning, 32 also tends to be more transformative (medium confidence). | 2964 - 296 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | Health care systems** Facilities in poor communities are often poorly sited and can lack capacity to support Universal health coverage can be highly beneficial to poor people (Atun et al., 2015), ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 17 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 17-28 Total pages: 156 people during climate-related extreme events (Codjoe et al., 2020). | 2966 - 2967 | | | |
| IPCC_AR6_WGII_Full_Report | 1 2 3 17.2.2.5 Incremental and Transformational Adaptation for Managing Risk in the Context of Adaptation 4 Limits 5 6 With evidence on soft and hard limits being experienced in natural and human systems including in 7 terrestrial, aquatic and marine ecosystems, coastal and island systems, agriculture, health systems, urban 8 spaces and tourism (Table 16.5, 16.4.2, medium confidence) transformation is also being considered to 9 expand the adaptation space beyond soft limits and before hard limits are being reached. As a key area of 10 advancement since AR5, this section assesses the relationship of residual risks, limits and incremental as 11 well transformational adaptation integrating the assessment of limits in 16.4 with ch.17 adaptation and risk 12 management assessment along a spectrum of adaptation change. 17.2.2.5 thus contributes to understanding 13 in which systems and regions transformational adaptation is increasingly required and considered once 14 incremental adjustments are exhausted in the context of soft and hard limits. | 2967 - 296 | 'rot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | 21 22 Planned adaptation can help to buy some limited time including through recovery and restoration efforts that 23 target resistant coral populations and interventions to culture heat-tolerant algal symbionts as well as by 24 setting up marine protected areas. Under higher warming levels, transformation has been proposed as 25 possibly complementing available management approaches with high-risk interventions, including enhanced 26 corals and reef shading, which may help to sustain some coral reef systems beyond 1.5°C of global warming. | 2969 - 296 | 'rot-Adapt-Mitig-Impa | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 34 35 In terms of planned adaptation options that would provide benefits to populations, evidence suggest these are 36 very limited, uncertain and bring along substantial risks to people, culture and ecosystems (3.5.2. Cross- 37 Chapter Box SLR). Concurrent with the loss of coral reefs important ecosystem services, including to RKR-E: Risk to human health from heat • Observed impacts • Projected risks • Incremental adaptation complemented by • Transformational adaptation • Soft limit (to incremental adaptation) • Hard limit Confidence: * low ** medium *** high **** very high ***** virtually certain Global • Heat is a significant health risk due to widespread urbanization, demographic changes and increase in hot weather (***) 323,000 estimated heat-related deaths and 13 million heat-related DALYs in 2019 • Temperature-related mortality expected to increase under medium and high heating scenarios even with adaptation. By 2050 (compared to 1961-1991) an excess of 94,000 deaths per year attributable to climate change projected due to heat for medium warming. | 2969 - 296 | 'rot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | • Limited evidence reported. early warning and response systems; integrating climate services into health decision-making systems; public uptake and buy in; improving health data collection systems • No evidence if transformational adaptation. • Reduced habitability of small islands through a compounding of key risks including from heat-related health stress for warming of 1.5 ° degrees (***) ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 17 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 17-31 Total pages: 156 1 fishery, tourism and coastal protection would be lost. Transformational adaptation, while requiring to make 2 difficult choices, is being discussed to help overcome soft limits through livelihood diversification for 3 alternative income sources, assisted migration and planned relocation of communities dependent on the 4 services provided by the reef ecosystem (medium confidence) (3.5.2). | 2969 - 297 | 'rot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | 17 18 There is evidence that, without strong risk management and adaptation, losses and damages will continue to 19 affect the poorest vulnerable populations potentially creating poverty traps (high confidence) (8.3; 8.4.5.6 20 and Table 8.7; 17.2; Serdeczny, 2019; Tschakert et al., 2019; Thomas et al., 2020). Research has started to 21 develop global inventories on losses and damages including on intangible effects (Tschakert et al., 2019; 22 Otto et al., 2020) and engaged with the practice community for data collection. Practice has provided 23 guidance to report on losses and damages in countries' (I)NDCs (WWF & Practical Action, 2020). Yet, 24 systematic risk assessments of climate-related losses and damages including adaptation limits (see, e.g. Leal 25 Filho and Nalau, 2018; Robinson, 2018) have remained scarce (16.4; high confidence). Thus many 26 vulnerable countries lack comprehensive data at scale of risk management including on economic (e.g. loss 27 of livelihood assets and infrastructure), and non-economic losses and damages (e.g. culture, health, 28 biodiversity) thus hampering effective risk management (Thomas and Benjamin, 2018; Martyr-Koller et al., 29 2021; Singh et al. 2021). van den Homberg and McQuistan (2019) propose a losses and damages inventory 30 also to be used to monitor how technologies may shape risks as well as adaptation limits. While early 31 warning and other risk reduction options as well as risk retention considerations are being discussed, L&D 32 dialogue has strongly focussed on risk finance for residual risks, particularly through the donor-supported 33 provision of public insurance systems (Linnerooth-Bayer et al., 2019; Schäfer et al., 2019; Broberg and 34 Romera, 2020; Nordlander et al., 2020). | 2971 - 297 | 'rot-Adapt-Mitig-Impa | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | Multi-Criteria Decision Analysis (MCDA): Partial ranking (Roy, 1996; Bell et al., 2001; Belton and Stewart, 2002; Bouyssou et al., 2006; Behzadian et al., 2010; Zopounidis and Pardalos, 2010; Tzeng and Huang, 2011; Bouyssou and others, 2012; De Smet and Lidouh, 2012; Velasquez and Hester, 2013; Figueira et al., 2016; Govindan and Jepsen, 2016) Examples include developing criteria for assessing climate protection strategies and applying these to retrofitting a school to manage climate risks in Germany (Markl-Hummel and Geldermann, 2014); evaluating outranking approaches for managing heat stress in a large city in Australia (El-Zein and Tonmoy, 2015); using MCDA to manage the interactions of climate change with tourism in Greece (Michailidou et al., 2016); and identifying priorities to manage droughts and floods in agriculture in Bangladesh (Xenarios and Polatidis, 2015). | 2985 - 298 | 'rot-Adapt-Mitig-Impa | | |

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| IPCC_AR6_WGII_Full_Report | 39 40 17.3.1.3.2 Stakeholder engagement 41 Stakeholder engagement has become increasingly part of climate-relevant decision processes (Orlove et al., 42 2020). The degree of stakeholder engagement ranges from instructive, consultative to cooperative that are 43 equivalent to information exchange, influence, and partners in decision-making (Sen, 2000; Cattino and 44 Reckien, in press). Since the AR5, climate change adaptation and resilience literature has seen an increase in 45 participatory approaches that deepen engagement and overcome challenges, as well as making some 46 assessments of their effectiveness (Newton Mann et al., 2017; Wamsler, 2017; Esteve et al., 2018), including 47 structured interactions among different types of stakeholders, the use of place-based boundary organizations 48 to strengthen the interactions and heighten the awareness of the institutional context. A higher degree of 49 public participation can lead to more transformational adaptation as well as to higher ambition for local 50 mitigation (medium confidence) (17.4.4.2; Cattino and Reckien, in press). Challenges to stakeholder 51 participation are access to state-of-the-art science, capacity to recognize and respond to non-reliable or false 52 climate science information, and the removal of cognitive and other biases (high confidence) (Gorddard et 53 al., 2016; Engler et al., 2019; Fulton, 2021). | 2988 - 298 | 'rot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | 26 This can identify the range of existing legislative instruments that can directly intersect with climate change, 27 along with related contextual factors such as national circumstances, governance frameworks, and political 28 and economic realities as well as national administrative culture (Scotford et al., 2017). This helps any new 29 climate change laws to be absorbed into, and harmonise with, the established legal system of each country 30 (Scotford et al., 2017). Efforts are underway to assist countries in such assessments and the identification of 31 areas for legislative reform, for example through the Commonwealth and UN Environment's Law and 32 Climate Change Toolkit. Similarly, databases such as the Grantham Research Institute on Climate Change 33 and the Environment and the Sabin Center on Climate Change Law are expanding the knowledge base of 34 national climate legislation developments. | 2996 - 2996 | | | |
| IPCC_AR6_WGII_Full_Report | 6 7 Several other international agreements including the Sendai Framework for Disaster Risk Reduction and the 8 UN Agenda 2030 Sustainable Development Goals have had significant impacts on the adaptation and risk- 9 management decision-making processes. For example, the Sendai Framework articulates the need for 10 improved understanding of disaster risk in all its dimensions of exposure, vulnerability and hazard 11 characteristics; accountability for disaster risk management; preparedness to "Build Back Better"; 12 recognition of stakeholders and their roles; mobilization of risk-sensitive investment to avoid the creation of 13 new risk resilience of health infrastructure, cultural heritage and workplaces; strengthening of international 14 cooperation and partnership, and risk-informed donor policies and programs, including financial support and 15 loans from international financial institutions. | 2998 - 299 | 'rot-Adapt-Mitig-Impact | | |
| IPCC_AR6_WGII_Full_Report | 8 9 Practitioner knowledge—the pragmatic, practice-based knowledge that comes from the regular exercise of 10 craft or professional work—was also acknowledged briefly in AR5 (Jones et al., 2014) and treated 11 significantly in SROCC (Abram et al., 2019). Practitioner knowledge resembles local knowledge in that it is 12 acquired through participation in activities, and yet it differs from local knowledge, which is often place- 13 based and tied directly to specific landscapes and communities. Local knowledge typically covers a variety 14 of environmental domains. Practitioner knowledge may be shared with people in different locations and is 15 often more focused on a narrower set of work activities. Recent calls have recommended bringing 16 practitioners more fully into the IPCC assessment process, to promote more effective decision-making 17 (Howarth et al., 2018). | 3011 - 301 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 25 26 The perception of climate change as a major threat that requires action has increased since AR5, reflecting 27 both the growth of information about climate change and the processing of that information (Lee et al., 2015; 28 Fagan and Huang, 2019). Global social movements play an important role in raising public awareness of 29 climate urgency (Thackeray et al., 2020). Climate change concern plays an important role in decision- 30 making outcomes which entail public participation (Lammel, 2015; Chiang, 2018; van Valkengoed and Steg, 31 2019; Arıkan and Günay, 2020). Nonetheless, public risk perception varies sharply on spatial and temporal 32 scales, reflecting environmental changes, social influences (Kousser and Tranter, 2018; Rousseau and 33 Deschacht, 2020), economic capacities (Arıkan and Günay, 2020) and culture (Noll et al., 2020), as well as 34 individual characteristics (van Valkengoed and Steg, 2019). The importance of values and norms is 35 demonstrated by recent research which highlights how intrinsic motivation (altruistic, self-transcendental and 36 ecocentric values) (Corner et al., 2014; Braito et al., 2017; Xiang et al., 2019; Bouman et al., 2020) and 37 extrinsic social motivation (e.g., economic gains and social desirability) (van Valkengoed and Steg, 2019) 38 can drive action. | 3014 - 301 | Impact | INTANBILE | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 13 14 Extreme events such as disasters often act as proximate drivers of windows of opportunity (Birkmann and 15 Fernando, 2008; McSweeney and Coomes, 2011). Climate disasters in a specific location become significant 16 windows for new debate, policymaking and financing (McSweeney and Coomes, 2011). Extreme events also 17 can facilitate change at locations distant from the most impacted site when remote actors gain perspective on 18 their own risks (Friedman et al., 2019; Solecki et al., 2019). Factors that facilitate extreme events driving 19 proactive as opposed to reactive responses include access to relevant risk and vulnerability data, pre-existing 20 experience with similar events, and appropriate governance (Brown et al., 2017a). Page and Dilling (2020) 21 find that worldview or ideology plays a central role in sense-making and in shaping what organizational 22 decision-makers 'see' in terms of acceptable actions in response to an extreme event. | 3017 - 301 | Impact | | |
| IPCC_AR6_WGII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 17 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 17-81 Total pages: 156 1 2 These movements usually focus on climate mitigation but sometimes include adaptation. Their social bases 3 include groups which had not previously been active in climate politics, notably children and youth, as well 4 as sectors with long traditions of environmental activism, such as women and Indigenous peoples (see Cross- 5 Chapter Boxes GENDER and INDIG in Chapter 18). Much of the literature on youth movements traces the 6 emergence of the movements themselves (Sanson et al., 2019; Treichel, 2020), their framings of climate 7 change as a social justice issue (Holmberg and Alvinius, 2019) and their presence in demonstrations and on 8 social media (Boulianne et al., 2020). Climate action catalysed by youth and other climate movements 9 include visible international events such as the signing of Declaration on Children, Youth, and Climate 10 Action at COP25 in Madrid 2019 (Han and Ahn, 2020), as well as national efforts, including lawsuits, and 11 local events such as in tree-planting and waste reduction initiatives (Bandura and Cherry, 2019). | 3019 - 302 | Prot-Adapt-Mitig- | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 6 7 8 [START BOX 17.3 HERE] 9 10 Box 17.3: Climate Risk Decision-Making in Settlements: From Incrementalism to Transformational 11 Adaptation 12 13 Cities are important sites of experimentation where the integration and management of adaptation decision- 14 making complexity often takes place. These actions provide early evidence of what aspects of complex 15 climate risk management decision-making functions well, but also what does not work (Revi et al., 2020). | 3021 - 302 | 'rot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | 22 Three key sets of drivers influence risk management decision-making in cities (Solecki et al., 2017). These 23 include 1) root – i.e., cultural norms and social traditions; 2) context – i.e., policy and governance conditions 24 and 3) proximate – i.e., extreme events. Settlements have developed informal and formal strategies including 25 climate protection levels to respond to local conditions of climate risk and hazards. In formal contexts, these 26 strategies are contextualized in local climate change action plans (Araos et al., 2016a; Stults and Woodruff, 27 2017; Reckien et al., 2018a; Singh et al., 2021) and defined around a set of evaluation tools and methods and 28 building codes, standards, and regulations (see discussion in 17.4.4). | 3021 - 302 | 'rot-Adapt-Mitig-Impa | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 26 27 Under the Paris Agreement countries are encouraged to provide information on adaptation including its 28 adequacy and effectiveness (Möhner et al., 2017; Adaptation Committee, 2021). National adaptation M&E 29 systems can inform both national as well as international reporting and contribute to the global stocktake (see 30 Cross-Chapter Box PROGRESS in this Chapter; Craft and Fisher, 2015; Leiter et al., 2017a). Guidance for 31 and examples of national adaptation progress assessments are provided by Price-Kelly et al. (2015); Brooks 32 et al. (2014); Brooks et al. (2019); EEA (2015); GIZ (2017); Karani (2018); and van Rüth and Schönthaler 33 (2018). Global assessments of adaptation progress have so far often focused on adaptation planning and, to a 34 lesser extent, implementation whilst evidence of the collective effect of adaptation globally remains limited 35 (high confidence) (UNEP, 2021a; Cross-Chapter Box PROGRESS in this Chapter). | 3033 - 303 | 'rot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | 37 38 Assessing global progress on adaptation is therefore of high relevance to the scientific community, to policy 39 makers and other actors. Global assessments serve different information needs than local assessments and 40 their meaningfulness depends on the chosen approaches and their limitations. Aggregated global assessments 41 of adaptation progress are therefore not meant to substitute place-specific ones but to complement them to 42 enhance the knowledge base on adaptation beyond actions by or within individual countries. The Paris 43 Agreement stipulates a Global Stocktake to be undertaken every five years to assess the collective progress 44 towards its long-term goals including on adaptation (UNFCCC, 2015, Article 14). Yet very few scientific 45 studies have addressed the adaptation-specific aspects of the Global Stocktake (Craft and Fisher, 2018; 46 Tompkins et al., 2018) and there are different views and options on how assessing global progress could take 47 place (high confidence). | 3035 - 303 | Prot-Adapt-Mitig- | | |

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| IPCC_AR6_WGII_Full_Report | 9 10 Learning requires information about how and why change occurred and what experiences have been made 11 (Feinstein, 2012). M&E is frequently associated with learning, but it is rarely made explicit how learning is 12 supposed to take place (Armitage et al., 2008; Baird et al., 2015; Borras and Hølund, 2015). The design of 13 adaptation M&E systems can support learning by gathering relevant information and disseminating it in a 14 way that is accessible and effectively linked to decision making processes (Spearman and McGray, 2011; 15 Villanueva, 2012; Fisher et al., 2015). Options include institutionalised feedback mechanisms, peer learning 16 and knowledge sharing events, a learning culture and ways to gather in-depth insights beyond indicators 17 (ibid; Oswald and Taylor, 2010). Since AR5, adaptation programmes and funds such as the BRACED 18 programme, the Adaptation Fund, the Climate Investment Funds and the Green Climate Fund have created 19 knowledge-sharing units and provide resources to support learning activities(BRACED, 2015; Roehrer and 20 Kouadio, 2015; Adaptation Fund, 2016; Leavy et al., 2018; CIF, 2020; Puri et al., 2020), but there is little 21 information about their longer-term effectiveness. | 3040 - 304 | 'rot-Adapt-Mitig-Impa( | | |
| IPCC_AR6_WGII_Full_Report | 15 16 In a warming world, incremental adaptation, i.e. proven standard measures of adaptation, will not always 17 suffice to adjust to the negative impacts from climate change leading to substantial residual risks and, in 18 some cases, the breaching of adaptation limits; transformational adaptation, involving larger system-wide 19 change (as compared to in system change), will increasingly be necessary as a complement for helping 20 individuals and communities to cope with climate change. As an example of incremental adaptation, a 21 farmer may decide to use drought-tolerant crops to deal with increasing occurrences of heatwaves. With 22 further warming and increases in heat waves and drought, however, the impacts of climate change may 23 necessitate the consideration of system-wide change, such as moving to an entirely new agricultural system 24 in areas where the climate is no longer suitable for current practices; or switching to livestock rearing. Where 25 on-site adaptation becomes infeasible and pull factors exist, the farming households may decide to seek 26 employment in other sectors, which may also lead to migration for work. As another example, physical 27 protection through sea walls to stop coastal flooding is a proven adaptation measure. With further projected 28 flooding due to increasing sea level rise attributable to climate change transformational city planning, that 29 would systemically change how flood water is managed throughout the whole city requiring deeper 30 institutional, structural, and financial support, may become necessary. Also, the deliberate relocation of 31 settlements (managed retreat) is seeing attention in the face of increasingly severe coastal or riverine 32 flooding in some regions. While transformational adaptation is increasingly being considered in theory and 33 planning, implementation is only beginning to see attention. | 3045 - 304 | 'rot-Adapt-Mitig-Impa( | | |
| IPCC_AR6_WGII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 18 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 18-12 Total pages: 197 1 2 3 4 Figure 18.2: Societal choices in arenas of engagement shaping actions and systems. The settings, places and spaces 5 in which key actors from government, civil society and the private sector interact to influence the nature and course of 6 development can be called arenas of engagement, including political, economic, socio-cultural, ecological, knowledge- 7 technology and community arenas. For instance, political arenas include formal political settings such as voting 8 procedures to elect local representatives as well as less formal and transparent political arenas. Streets, town squares 9 and post-disaster landscapes can become sites of interaction and political struggle as citizens strive to have their voices 10 heard. Arenas exist across scales from the local to national level, and beyond. Arenas of engagement can take the form 11 of “struggle arenas” – in which power and influence are used to include/exclude, set agendas, and make and implement 12 decisions – with inevitable winners and losers. The quality of interactions in these arenas leads to development 13 outcomes that can be characterized as CRD dimensions that underpin the SDGs – people, prosperity, partnership, peace, 14 planet (see Figure 18.1). a) Interactions characterized by inequitable relations and domination of some actors over 15 others may lead to societal choices away from CRD, including exacerbating disempowerment and vulnerability among 16 marginalized groups. b) Prospects for moving towards CRD increase when governance actors work together 17 constructively in these different arenas. Interactions and actions that are inclusive and synchronous, as opposed to 18 fragmented or contradictory, enable system transitions and transformational change towards CRD (Figure 18.3b, Box 19 18.3). b) Well-intentioned efforts often fail to be transformative, but instead entrench inequities. Instead, marginalized 20 groups and future trends in vulnerability need to be placed at the center of efforts to chart CRDPs. Unlocking the 21 productive potential of conflict that often characterizes interactions in these arenas of engagement is central to 22 advancing human well-being and planetary health. Moreover, the window for doing so is closing rapidly to avert 23 dangerous climate change and unsustainable development. | 3106 - 3107 | | | |

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| IPCC_AR6_WGII_Full_Report | 20 21 [END BOX 18.1 HERE] 22 23 24 [START BOX 18.2 HERE] 25 26 Box 18.2: Visions of Climate Resilient Development in Kenya 27 28 The Government of Kenya's (GoK) ambition is to transform Kenya into a 'newly industrializing, middle- 29 income country providing a high-quality life to all its citizens by 2030 in a clean and secure environment' 30 (Government of Kenya, 2008). Dryland regions in Kenya occupy 80-90 per cent of the land mass, are home 31 to 36% of the population (Government of Kenya, 2012) and contribute about 10 per cent of Kenya's Gross 32 Domestic Product (GDP) (Government of Kenya, 2012) which includes half of its agricultural GDP 33 (Kabubo-Mariara, 2009). In dryland regions, pastoralism has long been the predominant form of livelihood 34 and subsistence (Catley et al., 2013; Nyariki and Amwata, 2019). The GoK seeks to improve connectivity 35 and communication infrastructure within the drylands to better exploit and develop livestock, agriculture, 36 tourism, energy, and extractive sectors (Government of Kenya, 2018). It argues that the transformation of 37 dryland regions is crucial to enhance the development outcomes for the more than 15 million people who 38 inhabit these areas (Government of Kenya, 2016: 17) and to help the country to realize its wider national 39 ambitions including a 10 percent year on year growth in GDP (Government of Kenya, 2012). A key element 40 within this vision is the promotion and implementation of the Lamu Port South Sudan Ethiopia (LAPSSET) 41 project, a 2,000km long, 100 km wide economic and development corridor extending from Mombasa to 42 Sudan and Ethiopia (Enns, 2018). Supporters of the LAPSSET project argue that it will help achieve 43 priorities laid out in the Vision 2030 by opening up poorly connected regions, enabling the development of 44 pertinent economic sectors such as agriculture, livestock and energy, and supporting the attainment of a 45 range of social goals made possible as the economy grows (Stein and Kalina, 2019). | 3112 - 3112 | | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 46 47 However, the development narrative surrounding LAPSSET remains controversial in its assumptions, not 48 least because it is being promoted in the context of a highly complex and dynamic social, economic and 49 biophysical setting (Cervigni and Morris, 2016; Atsiaya et al., 2019; Chome, 2020; Lesutis, 2020). Some of 50 the key trends driving contemporary and likely future change in dryland regions are changing household 51 organization, evolving customary rules and institutions at local and community levels, and shifting cultures 52 and aspirations (Catley et al., 2013; Washington-Ottombre and Pijanowski, 2013; Tari and Pattison, 2014; 53 Cormack, 2016; Rao, 2019). Dryland regions are also witnessing demographic growth and change in land- 54 use patterns linked to shifts in the composition of livestock (for example from grazers to browsers), a 55 decrease in nomadic and increase in semi-nomadic pastoralism, and transition to more urban and sedentary 56 livelihoods (Mganga et al., 2015; Cervigni et al., 2016; Greiner, 2016; Watson et al., 2016). At a landscape 57 level, land is becoming more fragmented and enclosed, often associated with increases in subsistence and ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 18 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 18-18 Total pages: 197 1 commercial agriculture, and the establishment of conservancies and other group or private land holdings 2 (Reid et al., 2014; Carabine et al., 2015; Nyberg et al., 2015; Greiner, 2016; Mosley and Watson, 2016). In 3 addition, there are political dynamics associated with Kenya Vision 2030 and decentralization, the influence 4 of international capital, foreign investors and incorporation into global markets (Cormack, 2016; Kochore, 5 2016; Mosley and Watson, 2016; Enns and Bersaglio, 2020), as well as increasing militarization and conflict 6 in the drylands (Lind, 2018). Allied to these social and political dynamics are ongoing processes of habitat 7 modification and degradation and biophysical changes linked in part to climate variability (Galvin, 2009; 8 Mganga et al., 2015). The interconnected nature of these drivers will intersect with LAPSSET in myriad 9 ways. For example, the implementation of LAPSSET may accentuate some trends, such as increases in land 10 enclosure and a shift towards more urban and sedentary livelihoods (Lesutis, 2020). Conversely, the 11 perceived threat LAPSSET could pose to pastoral lifestyles may lead to greater visibility, solidarity and 12 strength of pastoralist institutions (Cormack, 2016). | 3112 - 3113 | | INTANBILE | |

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| IPCC_AR6_WGII _Full_Report | 13 14 There is a recognized need to adapt and chose development pathways that are resilient to climate change 15 whilst addressing key developmental challenges within dryland regions, notably, poverty, water and food 16 insecurity, and a highly dispersed population with poor access to services (Government of Kenya, 2012; 17 Bizikova et al., 2015; Herrero et al., 2016). The current vision for development of dryland regions comes 18 with both opportunities and threats to achieve a more climate resilient future. For example, the growth in and 19 exploitation of renewable energy resources, made possible through increased connectivity, brings climate 20 mitigation gains but also risks. These risks include the uneven distribution of costs in terms of where the 21 industry is sited compared with where benefits primarily accrue, and may exacerbate issues around water 22 and food insecurity as strategic areas of land become harder to access (Opiyo et al., 2016; Cormack and 23 Kurewa, 2018; Enns, 2018; Lind, 2018). Whilst LAPSSET will bring greater freedom of movement for 24 commodities, benefitting investors, improving access to markets and urban centers, supporting trade, or ease 25 of movement for tourists supporting economic goals, it can also result in the relocation of people and impede 26 access to certain locations for the resident populations. Mobility is a key adaptation behavior employed in 27 the short and long term to address issues linked with climatic variability (Opiyo et al., 2014; Muricho et al., 28 2019). With modelled changes in the climate suggesting decreases in income associated with agricultural 29 staples and livestock-dependent livelihoods, development that constrains mobility of local populations could 30 retard resilience gains (Ochieng et al., 2017; ASSAR, 2018; Enns, 2018; Nkemelang et al., 2018). The likely 31 increase in urban populations and the growth in tourism and agriculture may lead to increases in water 32 demand at a time when water availability could become more constrained owing to the reliance on surface 33 water sources and the modelled increases in evapotranspiration due to rising mean temperature, more 34 heatwave days and greater percentage of precipitation falling as storms (ASSAR, 2018; Nkemelang et al., 35 2018; USAID, 2018). These pressures could make it harder to meet basic health and sanitation goals for rural 36 and poorer urban populations, issues compounded further by likely increases in child malnutrition and 37 diarrheal deaths linked to climate change (WHO, 2016; ASSAR, 2018; Hirpa et al., 2018; Nkemelang et al., 38 2018; Lesutis, 2020). Development must pay adequate attention to these interconnections to ensure that costs 39 and benefits of achieving climate mitigation and adaptation goals are distributed fairly within a population. | 3113 - 311 | ʼrot-Adapt-Mitig-Impa( | | |
| IPCC_AR6_WGII _Full_Report | 49 50 One common approach for exploring the implications of different development trajectories is the use of 51 scenarios of future socioeconomic conditions, such as the Shared Socioeconomic Pathways (SSPs) (O'Neill 52 et al., 2017). The SSPs represent sets of future global societal assumptions based on different societal, 53 technological, and economic assumptions that result in different development trajectories. Such scenarios 54 often correspond to a small set of scenario archetypes (Harrison et al., 2019; Sitas et al., 2019; Fergnani and 55 Song, 2020) in that they reflect core themes regarding the future of development such as sustainability versus 56 rapid growth. Scenarios with assumptions more closely aligned with sustainability agendas (e.g., SSP1- 57 Sustainability) commonly imply lower greenhouse gas emissions and projected climate change (see WGIII ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 18 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 18-23 Total pages: 197 1 AR6 Chapter 3), lower mitigation costs for ambitious climate goals (see WGIII AR6 Chapter 3), lower 2 climate exposure due in large part to the size of society (see Chapter 16), and greater adaptive capacity (Roy 3 et al., 2018) (see also Chapter 16). In contrast, scenarios with rapid global economic and fossil energy 4 growth (e.g., SSP5-Fossil-Fueld Development) imply higher emissions and project climate change, higher 5 mitigation costs, as well as greater social and economic capacity to adapt to climate change impacts (Hunt et 6 al., 2012) (Table 18.1). | 3117 - 311 | ʼrot-Adapt-Mitig-Impa( | INTANBILE | |

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| IPCC_AR6_WGII_Full_Report | Developmen t Indicator Releva nt SDG Shared Socioeconomic Pathway Confiden ce Evidence/ Agreeme nt References Sustainabili ty (SSP1) Middl e of the Road (SSP2 ) Region al Rialry (SSP3) Inequalit y (SSP4) Fossil�fueled Developme nt (SSP5) Agriculture, Food, & Forestry •Agriculture production •Forestry production •Food security •Hunger SDG 2 & 1 ( ( ( Low Agreemen t/ Robust Evidence (Hasegawa et al., 2015; Palazzo et al., 2017; Riahi et al., 2017; Duku et al., 2018; Chen et al., 2019; Daigneault et al., 2019; Mitter et al., 2020; Mora et al., 2020) Health & Well-Being • Exces s mortality • Air quality SDG 3 1 1 1 ( ( Medium Agreemen t/ Robust Evidence (Chen et al., 2017; Mora et al., 2017; Aleluia Reis et al., 2018; Asefi�Najafabady ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 18 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 18-24 Total pages: 197 • Vecto r-borne disease • Life Satisfaction et al., 2018; Chen et al., 2018; Harrington and Otto, 2018; Marsha et al., 2018; Sellers and Ebi, 2018; Ikeda and Managi, 2019; Rohat et al., 2019; Wang et al., 2019; Chae et al., 2020) Water & Sanitation • Water use • Sanitation access • Sewage discharge SDG 6 & ( ( 1 1 High Agreemen t/ Medium Evidence (Wada et al., 2016) (van Puijenbroek et al., 2014; Yao et al., 2017) (Mouratiad ou et al., 2016; Graham et al., 2018) Inequality • Gini coefficient SDG 10 & & & 1 & Medium Agreemen t/ Limited Evidence (Rao et al., 2019b; Emmerling and Tavoni, 2021; Gazzotti et al., 2021) Ecosystems and Ecosystem Services •Aquatic resources •Urban expansion •Habitat provision •Carbon sequestrati on •Biodiversit y SDG 14 SDG 15 ( ( ( ( ( High Agreemen t/ Medium Evidence (Li et al., 2017; Chen et al., 2019; Li et al., 2019b; Chen et al., 2020b; Song et al., 2020b; McManama y et al., 2021; Pinnegar et al., 2021) Legend $ Balance of studies suggest large increasing threat to sustainable development ( Balance of studies suggest moderate increasing threat to sustainable development 1 Studies suggest both threats and benefits to sustainable development & Balance of studies suggest moderate increasing benefit to sustainable development # Balance of studies suggest large increasing benefit to sustainable development Table Notes: Studies presented in the above table include qualitative storylines and quantitative scenarios for two or more SSPs. | 3118 - 3119 | | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 26 27 28 [START BOX 18.3 HERE] 29 30 Box 18.3: Climate Resilient Development in Small Islands 31 32 Small Islands are particularly vulnerable to climate change and many are already pursuing climate resilient 33 development pathways that enable integrated responses (Allen et al., 2018a; Mycoo, 2018; Hay et al., 2019; 34 Robinson et al., 2021). Countries, such as Belize, have opted for a systems-approach and are working across 35 the SDGs to increase integration (Allen et al., 2018a). This includes rethinking disaster reconstruction 36 mechanisms in the Caribbean and introducing more diversified and sustainable tourism economies that can 37 better withstand external shocks such as disruptions and loss of markets from COVID-19 (Sheller, 2021). In 38 the Seychelles, various government and tourism industry initiatives are focused on the promotion of 39 sustainable tourism ventures that lower emissions, protect and promote biodiversity conservation (e.g. new 40 marine protected areas with mitigation and adaptation benefits), and are climate resilient (Robinson et al., 41 2021). In 2016 the Seychelles signed the world's first nature-for-debt swap wherein an NGO (The Nature 42 Conservancy) agreed to pay off Seychelles' public debt to the Paris Club (foreign creditors) in return for the 43 Seychelles government establishing marine conservation areas (Silver and Campbell, 2018). | 3125 - 312 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | 44 45 One key area where enhanced climate risk integration is critical is infrastructure-related decisions especially 46 on coastal areas (World Bank, 2017). However, despite increasing awareness of climate risks and 47 experienced impacts, decisions on for example infrastructure locations still reflect cultural preferences. For 48 example, Hay et al. (2019) report that despite recommendations to relocate the redevelopment site of the 49 Parliamentary Complex in Samoa away from the coast, multiple cultural and historical factors influenced the 50 decisions to redevelop at the original site. In the Solomon Islands, however, emerging evidence suggests that 51 adaptation efforts to enhance the resilience of infrastructure are also serving to help urban areas address 52 problems associated with rapid urbanization and provide new opportunities for sustainable development 53 (Robinson et al., 2021). | 3125 - 312 | 'rot-Adapt-Mitig-Impac | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 53 54 Focusing on bottom-up and community-led transformations, there is emphasis on the role of grassroots 55 organizations in transformations. Community actions around specific locations or topics have parallels to the 56 idea of transformative spaces. They are sites of innovative activity (Seyfang and Smith, 2007). Grassroots 57 organizations can bridge the local and the political scales by politicizing actors and creating new interactions ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 18 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 18-55 Total pages: 197 1 between individuals and political processes (Novák, 2021). They are a collective approach to pushing for 2 both individual and societal change (Sage et al., 2021). | 3149 - 3150 | | | |

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| IPCC_AR6_WGII_Full_Report | 52 53 54 18.4 Agency and Empowerment for Climate Resilient Development 55 56 As reflected in the discussion of societal transitions (18.3), people and their values and choices play an 57 instrumental role in CRD. The agency of people to act on CRD is grounded in their worldviews, beliefs, ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 18 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 18-65 Total pages: 197 1 values, and consciousness (Woiwode, 2020) and is shaped through social and political processes including 2 how policies and decision-making recognize the voices, knowledges and rights of particular actors over 3 others (very high confidence) (Harris and Clarke, 2017; Nightingale, 2017; Bond and Barth, 2020; Muok et 4 al., 2021). Since the AR5, evidence on diverse forms of engagement by and among social, political and 5 economic actors to support climate resilient development and sustainability outcomes, has increased. New 6 forms of decision-making and engagement are emerging within the formal policy making and planning 7 sphere, including co-production of knowledge, interventions grounded in the arts and humanities, civil 8 participation and partnerships with business (Ziervogel et al., 2016a; Roberts et al., 2020). In addition, the 9 set of actors that drive climate and development actions are recognized to extend beyond government and 10 formal policy actors to include civil society, education, industry, media, science and art (Ojwang et al., 2017; 11 Solecki et al., 2018; Heinrichs, 2020; Omukuti, 2020). This makes the power dynamics among actors and 12 institutions critical for understanding the role of actors in CRD (Buggy and McNamara, 2016; Camargo and 13 Ojeda, 2017; Silva Rodríguez de San Miguel, 2018). | 3159 - 3160 | | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 7 8 One output from systems of governance is formal policy frameworks and policies that influence processes 9 and outcomes of system transitions that support CRD (18.1.3). The Paris Agreement, for example, provides a 10 framework for CRD by defining a mitigation-centric goal of 'limiting warming to well below 2°C and 11 enabling a transition to 1.5°C' (UNFCCC, 2015). It also provides for a broadly defined global adaptation 12 goal (UNFCCC, 2015: Art. 7.1). The Nationally Determined Contributions (NDCs) are the core mechanism 13 for achieving and enhancing climate ambitions under the Paris Agreement. However, the pursuit of a given 14 NDC within a specific country will likely necessitate a range of other policy interventions that have more 15 immediate impact on technologies and behavior, implicating transitions in energy, industry, land, and 16 infrastructure (very high confidence (18.3.1). SDG-relevant activities are increasingly incorporated into 17 climate commitments in the NDCs (at last count 94 NDCs also addressed SDGs), contributing to several 18 (154 out of the 169) SDG targets (Brandi and Dzebo; Pauw et al., 2018). This reflects the potential of the 19 NDCs as near-term policy instruments and sign-posts for progress toward CRD (medium agreement, limited 20 evidence) (McCollum et al., 2018b). | 3162 - 316 | 'rot-Adapt-Mitig-Impa( | | |
| IPCC_AR6_WGII_Full_Report | 54 55 [END BOX 18.7 HERE] 56 57 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 18 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 18-71 Total pages: 197 1 18.4.2.3 Institutional capacity 2 3 Institutional capacity for system transitions refers to the capacity of structures and processes, rules, norms, 4 and cultures to shape development expectations and actions aimed at durable improvements in human well- 5 being. The AR5 highlighted the need for strong institutions to create enabling environments for adaptation 6 and greenhouse gas mitigation action (Denton et al., 2014). Institutions stand within the social and political 7 practices and broader systems of governance that ultimately drive adaptation and development processes and 8 outcomes. They are thus produced by them and can become tools by which some actors constrain the actions 9 of others (Gebreyes, 2018). As a consequence, they and can become a significant barrier to change, whether 10 incremental or more transformational (very high confidence). The post-AR5 focus on transformational 11 adaptation and resilience present in the literature suggests that institutions that enable system transitions 12 toward CRD are secure enough to facilitate a wide range of voices, and legitimate enough to change goals or 13 processes over time, without reducing confidence in their efficacy. | 3165 - 316 | Prot-Adapt-Mitig- | INTANBILE | |

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| IPCC_AR6_WGII_Full_Report | 57 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 18 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 18-73 Total pages: 197 1 For example, political arenas range from formalized election and voting procedures to more informal and 2 less transparent practices, like special interest lobbying. Town squares and streets can become sites of 3 political struggle and dissent, including protests against climate inaction. As a more specific case-in-point, 4 the formal space for national, sub-national and international adaptation governance emerged at COP 16 5 (UNFCCC, 2010) when adaptation was recognized as having a similar level of priority as mitigation. The 6 Paris Agreement (UNFCCC, 2015) built on this and the 2030 Sustainable Development Agenda (United 7 Nations, 2015) to link adaptation to development and climate justice, widening the scope of adaptation 8 governance beyond formal government institutions. It also highlighted the importance of multi-level 9 adaptation governance, including non-state voices from civil society and the private sector. This implied the 10 need for wider arenas and modes of engagement around adaptation (Chung Tiam Fook, 2017; Lesnikowski 11 et al., 2017; IPCC, 2018a) that facilitate coordination and convergence among these diverse actors including 12 individual citizens to collectively solve problems and unlock the synergies between adaptation and 13 mitigation and sustainable development (IPCC, 2018a; Romero-Lankao et al., 2018). | 3167 - 316 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | 54 55 To address these difficult contests, climate- and global environmental change-related worldviews are often 56 scientized. This can exclude other worldviews which ultimately narrows understanding of climate change 57 and the solution space. Hence, the post-AR5 literature on worldviews focuses on the numerous meanings, ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 18 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 18-74 Total pages: 197 1 associations, narratives and frames of climate change and how these shape perceptions, attitudes and values 2 (Morton, 2013; Boulton, 2016; Hulme, 2018; Nightingale Böhler, 2019). The recognition of the diversity of 3 interpretations and meanings has led to multidisciplinary and transdisciplinary research that incorporates the 4 humanities and the arts (Murphy, 2011; Elliott and Cullis, 2017; Steelman et al., 2019; Tauginienė et al., 5 2020), feminist studies (MacGregor, 2003; Demeritt et al., 2011; Bell, 2013; Brink and Wamsler, 2019; 6 Plesa, 2019) and religious studies (Sachdeva, 2016; McPhetres and Zuckerman, 2018) to examine diverse 7 understandings of reality and knowledge possibilities around climate change. In addition, literature on 8 cultural cognition, epistemological plurality and relational ontologies draws on non-Western worldviews and 9 forms of knowledge (Goldman et al., 2018) (Jackson, 2016; Nightingale, 2016; Xue et al., 2016). | 3168 - 3169 | | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 19 20 21 [START CROSS-CHAPTER BOX INDIG HERE] 22 23 Cross-Chapter Box INDIG: The Role of Indigenous Knowledge and Local Knowledge in 24 Understanding and Adapting to Climate Change 25 26 Authors: Tero Mustonen (Finland), Sherilee Harper (Canada), Gretta Pecl (Australia), Vanesa Castán Broto 27 (Spain), Nina Lansbury (Australia), Andrew Okem (Nigeria/South Africa), Ayansina Ayanlade (Nigeria), 28 Jackie Dawson (Canada), Pauline Harris (Aotearoa-New Zealand), Pauliina Feodoroff (Finland), Deborah 29 McGregor (Canada) 30 31 Indigenous knowledge refers to the understandings, skills and philosophies developed by societies with long 32 histories of interaction with their natural surroundings (UNESCO, 2018; IPCC, 2019a). Local knowledge 33 refers to the understandings and skills developed by individuals and populations, specific to the places where 34 they live (UNESCO, 2018; IPCC, 2019a). Indigenous knowledge and local knowledge are inherently 35 valuable but have only recently begun to be appreciated and in western scientific assessment processes in 36 their own right (Ford et al., 2016). In the past these often endangered ways of knowing have been suppressed 37 or attacked (Mustonen, 2014). Yet these knowledge systems represent a range of cultural practices, wisdom, 38 traditions, and ways of knowing the world that provide accurate and useful climate change information, 39 observations, and solutions (very high confidence) (Table Cross-Chapter Box INDIG.1). Rooted in their own 40 contextual and relative embedded locations, some of these knowledges represent unbroken engagement with 41 the earth, nature and weather for many tens of thousands of years, with an understanding of the ecosystem 42 and climatic changes over longer-term timescales that is held both as knowledge by Indigenous Peoples and 43 Local Peoples as well as in the archaeological record (Barnhardt and Angayuqaq, 2005; | 3169 - 316 | Prot-Adapt-Mitig- | INTANBILE | INDG |

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| IPCC_AR6_WGII_Full_Report | 8 9 Multiple knowledge systems and frameworks 10 11 Indigenous knowledge systems include not only the specific narratives and practices to make sense of the 12 world, but also profound sources of ethics and wisdom. They are networks of actors and institutions that 13 organise the production, transfer and use of knowledge (Löfmarck and Lidskog, 2017). There is a pluralism 14 of forms of knowledge that emerge from oral traditions, local engagement with multiple spaces, and 15 Indigenous cultures (Peterson et al., 2018). Recognising such multiplicity of forms of knowledge has long 16 been an important concern within sustainability science (Folke et al., 2016). Less dominant forms of 17 knowledge should not be put aside because they are not comparable or complementary with scientific 18 knowledge (Brattland and Mustonen, 2018; Mustonen, 2018; Ford et al., 2020; Ogar et al., 2020). Instead, 19 Indigenous knowledge and local knowledge can shape how climate change risk is understood and 20 experienced, the possibility of developing climate change solutions grounded in place-based experiences, 21 and the development of governance systems that match the expectations of different Indigenous knowledge 22 and local knowledge holders (very high confidence). | 3170 - 317 | Impact | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 47 48 For climate research, the role of oral histories as a part of Indigenous knowledge and local knowledge is 49 extremely relevant. For example, ocean adaptation initiatives can be guided by oral historians and keepers of 50 knowledge who can convey new knowledge and baselines of ecosystem change over long-time frames 51 (Nunn and Reid, 2016). Oral histories can also convey cultural indicators and linguistic devices of species 52 identification as a part of a local dialect matrix and changes in ecosystems and species using interlinkages 53 not available to science (Mustonen, 2013; Frainer et al., 2020). Oral histories attached to maritime place 54 names, especially underwater areas (Brattland and Nilsen, 2011), can position observations relevant for 55 understanding climate change over long ecological timeframes (Nunn and Reid, 2016). Species abundances, 56 well-being and locations are some of the examples present in the ever-evolving oral histories as living ways 57 of knowing. Indigenous knowledge and oral histories may also have the potential to convey governance, ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 18 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 18-77 Total pages: 197 1 moral, and ethical frameworks of sustainable livelihoods and cultures (Mustonen and Shadrin, 2020) rooted 2 in the particular Indigenous or local contexts that are not otherwise available in written or published forms. | 3171 - 317 | Prot-Adapt-Mitig- | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | Latin America In Venezuela, Brazil, and Guyana, Indigenous knowledge systems have led to a lower incidence of wildfires, reducing the risk of rising temperatures and droughts (Mistry et al., 2016). The Mapuche Indigenous Peoples in Chile use various traditional and sustainable agricultural practices, including: native seed conservation and exchange (trafkintu), crop rotation, polyculture, and tree�crop association. They also give thanks to Mother Earth through rituals to nurture socioecological sustainability (Parraguez-Vergara et al., 2018). In rural Cusco Region of Peru, “cultures values known in Quechua as ayni (reciprocity), ayllu (collectiveness), yanantin (equilibrium) and chanincha (solidarity)” have led to successful adaptation to climate change (Walshe and Argumedo, 2016). | 3173 - 317 | 'rot-Adapt-Mitig-Impac | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 32 33 Subsidies 34 35 The World Bank has been encouraging both developed and developing states, especially those with petroleum 36 reserves, to use the removal of subsidies as a mechanism for promoting energy transitions away from fossil 37 fuels. The transition has led to social unrest in some cases, especially where there is a culture of entitlement to 38 low-cost energy because it is an indigenous resource. Such reforms have been more effective when 39 governments have been able to clearly show how savings are applied to social and health programs that benefit 40 human well-being. Nevertheless, policy makers should not underestimate the complexity of issues involved in 41 the removal of subsidies that will increase the cost of carbon and hasten the transition to cleaner fuels (Scobie, 42 2017; Scobie et al., 2018; Chen et al., 2020a). A crucial issue to take into account is the harmful effects some 43 subsidies have on biodiversity. Although governments agreed in 2010 to make progress on reducing subsidies 44 in 2010, by 2020 few governments had identified specific incentives to remove or taken action toward their 45 removal. Further investigation of the positive and negative effects of subsidy redirection or elimination on 46 people and the environment (Dempsey et al., 2020). | 3178 - 317 | Impact | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 31 32 Prompted by SR1.5, new youth movements seek to use science-based policy to break with incremental 33 reforms and demand radical climate action beyond emissions reductions (Hallam, 2019; Klein, 2020; 34 Thackeray et al., 2020; Thew et al., 2020). Recent social movements and climate protests embrace new 35 modalities of action related to political responsibility for climate injustice through disruptive collective 36 political action (Young, 2003; Langlois, 2014). This is complemented by a regenerative culture and ethics of 37 care (Westwell and Bunting, 2020). These new social movements are based on nonviolent methods of 38 resistance, including actions classified as dutiful, disruptive and dangerous dissent (O’Brien, 2018). | 3180 - 3180 | | INTANBILE | |

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| IPCC_AR6_WGII_Full_Report | • increase efficiency and equity of water management and allocation (14.4.3.3) • energy conservation measures (14.6.1.3) • guidelines, codes, standards, and specifications for infrastructure (14.6.1.6) • modifying zoning and buying properties in floodplains (14.6.1.3) • web-based tools for visualizing and exploring climate information scenario planning and risk analyses (s14.6.1.6) • (S+) Post-fire ecosystem recovery measures, restoration of habitat connectivity, and managing for carbon storage enhance adaptation potential and offers co-benefits with carbon mitigation (Box 14.1) • (T) REDD+ represents a trade-off between carbon mitigation and the ability of communities to improve their food security (14.4.7) • (T) New coastal and alpine developments generate economic activity but enhance local social inequalities (15.4.10) GINI 40.0 (33.3- 45.4) FRAGILITY 45.4 (21.7- 69.9) CO2/PC 11.9 (3.8-16.6) Small Islands PPAHDI 0.68 (0.51- 0.76) • high dependence of economic activity on tourism (15.3.4.5) • Lack of coordination among government departments (15.6.1) • limited regional cooperation (15.6.1) • increasing women's access to climate change funding and support from organizations (15.6.5)promoting agroecology, food sovereignty, and regenerative economies (15.7) • raising dwellings and other infrastructure (15.5.2) • land reclamation (15.5.2) • migration and planned resettlement (15.5.2) • ecosystem-based adaptation including Indigenous and local knowledge (15.5.2) • (S+) development decisions and outcomes are strengthened by consideration of climate and disaster risk (15.7) • (S-) impacts of invasive alien species on islands are projected to increase with GINI 40.2 (28.7- 56.3) FRAGILITY 64.6 (38.1- 97.5) ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 18 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 18-97 Total pages: 197 CO2/PC 3.7 (0.3-31.3) • absence of planning frameworks (15.6.1) • corruption and corrupt people in political and public life (15.6.1) • insufficient human capital (15.6.1) • competing development priorities (15.5.5) • lack of education and awareness around climate change (15.6.4) • failure of externally driven adaptation (15.6.5) • constraints on economic, legislative, and technical capacity of local governments (15.7) • expanding sustainable tourism economies (15.7) • integrating climate change and disaster management with broader development planning and implementation (15.7) • using climate risk insurance as a way to support development and adaptation processes (15.7) • improving cross sectoral and cross agency coordination (15.7) • enhanced integration between development assistance, public financial management, and climate finance (15.5.7) • protected areas (15.5.2) • ecosystem restoration and improved agroforestry practices (15.5.2 15.5.4) • community-based adaptation (15.5.5) • livelihood diversification and use of improved technologies and equipment (15.5.6) • diversifying cropping patterns, expanding or prioritizing other cash crops (15.5.6) • small-scale livestock husbandry (15.5.6) • irrigation technologies (15.5.6) • diversification away from coastal tourism • disaster risk management (DRM) (15.5.7) • early warning systems and climate services (15.5.7) time due to synergies between climate change and other drivers (15.3.3) • (S-) synergies between changing climate and other natural and anthropogenic stressors could lead to disproportionate impacts on biodiversity (15.3.3) 1 2 3 Table 18.7: Sectoral synthesis of dimensions of climate-resilient development. For each sectoral chapter of the WGII report, this table identifies those SDGs that are discussed in the 4 relevant chapter as being | 3191 - 319 | Prot-Adapt-Mitig-Impac | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 13 14 The more recent literature adds significant context to the concept of CRD, but also introduces broader 15 perspectives regarding its significance in the arena of climate action. Hence, concepts that are both 16 complementary to, and competitive with, CRD, such as climate safe', 'climate compatible' and 'climate 17 smart' development (Huxham et al., 2015; Kim et al., 2017b; Ficklin et al., 2018; Mcleod et al., 2019) 18 (18.1.1). These different framings of the intersection between sustainable development and climate action 19 are used in different communities of research and practice, which complicates efforts to provide clear 20 guidance to decision-makers regarding the goals of CRD and how best to achieve it. This is attributable in 21 part to persistent conceptual confusion and disciplinary divides over more fundamental concepts such as 22 resilience and sustainability (Rogers et al., 2020; Zaman, 2021), not to mention contested perspectives 23 regarding development (Lo et al., 2020; Song et al., 2020a; Morton, 2021) (medium agreement; medium 24 evidence). | 3199 - 3199 | | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 33 34 In this way, recent social movements and climate protests show new modalities of action related to political 35 responsibility for inaction based on contestation. The new climate movement led mostly by youngsters, 36 markedly seek science-based policy and more importantly, demand to break with a reformist stance and 37 social inertia through radical climate action. This is mostly done through collective disruptive action, and 38 non-violent resistance to promote awareness, a regenerative culture and ethics of care. These movements 39 have resulted in notable political successes, such as declarations of climate emergency at the national and 40 local level, as well as in universities. Also, their methods have proven effective to end fossil fuel 41 sponsorship. | 3203 - 320 | Impact | INTANBILE | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 24 25 CCB FEASIB.3.2.2 Sustainable aquaculture 26 There is medium evidence with medium agreement on the feasibility of sustainable aquaculture as an 27 adaptation measure. Sustainable aquaculture (e.g. Integrated Multi-Tropic Aquaculture, polyculture, 28 aquaponics, mangrove-integrated culture) can have socio-economic benefits for vulnerable communities and 29 small-scale fisheries (Ahmed, 2018; Blasiak et al., 2019; Mustafa et al., 2021; Thomas et al., 2021; Xuan et 30 al., 2021). Nevertheless, caution is important to guarantee that access to fish supply of local and vulnerable 31 communities is not affected (Chan et al., 2019; Galappaththi et al., 2020). Access to financial resources is 32 often a barrier to implementation, although sustainable aquaculture can increase employment opportunities 33 that are increasingly gender equitable (Alleway et al., 2018; Leakhena et al., 2018; Valenti et al., 2018; 34 Gopal et al., 2020), as well as increasing the resilience of coastal livelihoods to climate change (Shaffril et 35 al., 2017; Blasiak and Wabnitz, 2018). Technological, institutional and socio-cultural factors can form 36 barriers to the feasibility of sustainability of aquaculture (e.g. (Ahmed et al., 2018; Blasiak et al., 2019; 37 Galappaththi et al., 2019; Boyd et al., 2020; Osmundsen et al., 2020; Stentiford et al., 2020; Mustapha et al., 38 2021; Xuan et al., 2021). | 3255 - 325 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | 55 Sustainable agriculture is likely to receive strong support from many countries but may experience resistance 56 for several reasons (e.g., competition with existing industries, debates over tolerance to aesthetic changes to 57 coastlines). Literature on this area is growing and potential barriers at the government and political levels are ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 18 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 18-161 Total pages: 197 1 significant (e.g. (Jayanthi et al., 2018; Blasiak et al., 2019; Hargan et al., 2020; Osmundsen et al., 2020; 2 Stentiford et al., 2020; Mustafa et al., 2021; Qurani et al., 2021). | 3255 - 3256 | | | |
| IPCC_AR6_WGII_Full_Report | 14 15 Diverse socio-economic co-benefits have been identified, including integration of tourism activities, 16 increased educational opportunities for the reduction in storm damage, maintenance of ecosystems and their 17 services, increasing adaptive capacities of institutions (Romañach et al., 2018; Mestanza-Ramón et al., 2019; 18 Morris et al., 2019; Donatti et al., 2020; Ellison et al., 2020; Erftemeijer et al., 2020; Gómez Martín et al., 19 2020; Hanley et al., 2020a; Jones et al., 2020b; Martuti et al., 2020; Perera-Valderrama et al., 2020; Telave 20 and Chandankar, 2021); as well as environmental and geophysical co-benefits aspects, including mitigation 21 potential and hazard risk reduction (Propato et al., 2018; Romañach et al., 2018; Ellison et al., 2020; 22 Erftemeijer et al., 2020; Hanley et al., 2020a; Jones et al., 2020b; Martuti et al., 2020; Cantasano et al., 23 2021). | 3256 - 325 | 'rot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGII_Full_Report | 30 31 CCB FEASIB.3.2.6 Biodiversity management and ecosystem connectivity 32 There is robust evidence and medium agreement supporting the overall feasibility of biodiversity 33 management and ecosystem connectivity as adaptation options. With respect to its economic feasibility, 34 financial constraints continue to hinder broader implementation of biodiversity-based solutions (Lausche et 35 al., 2013; Chausson et al., 2020; Jones et al., 2020a).(Seddon et al., 2020a) highlights that only five percent 36 of climate finance goes towards adaptation strategies, and only one percent is destined to disaster risk 37 management including nature-based solutions and biodiversity management. Government support via 38 subsidies and fiscal transfers is critical for broader biodiversity management interventions. In addition, 39 REDD+ initiatives have been promoted as a profitable mechanism to advance biodiversity conservation 40 strategies while reducing carbon emissions. As far as ecosystem connectivity is concerned, its feasibility will 41 strongly depend on the existence of a regulatory framework that appropriately balances property rights, 42 environmental regulations and monetary incentives to ensure landowners' willingness to participate and 43 maintain ecosystem corridors (Jones et al., 2020b). The demands of commodity-based economies, favouring 44 extractive land-uses, present serious barriers to upscaling biodiversity-based adaptation interventions 45 (Seddon et al., 2020a). In addition, integrated assessments have shown how biodiversity-based solutions can 46 deliver jobs from landscape restoration or income from wildlife tourism and how those benefits are fairly 47 distributed (Chausson et al., 2020). | 3258 - 325 | 'rot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGII_Full_Report | 3 4 Several social co-benefits are found to follow from biodiversity management strategies, including improved 5 community health, recreational activities, eco-tourism, in addition to educational, spiritual and scientific 6 benefits (Lausche et al., 2013; Worboys et al., 2016; Seddon et al., 2020a). (Lavorel et al., 2020) show how 7 the benefits of biodiversity management are co-produced by harnessing ecological and social capital to 8 promote resilient ecosystems with high connectivity and functional diversity. Furthermore, (Chausson et al., 9 2020) note how properly implemented nature-based solutions, including biodiversity management, can 10 strengthen social networks and foster a sense of place, supporting virtuous cycles of community engagement 11 to sustain interventions over time. | 3259 - 3259 | | INTANBILE | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 35 36 CCB FEASIB.3.2.7 Improved cropland management 37 Improved cropland management, which includes agricultural adaptation strategies such as integrated soil 38 management, no/reduced tillage, conservation agriculture, planting of stress-resistant or early maturing crop 39 varieties, and mulching, has high economic and environmental feasibility (robust evidence, high agreement) 40 (AGEGNEHU and AMEDE, 2017; Lalani et al., 2017; Schulte et al., 2017; Thierfelder et al., 2017; Aryal et 41 al., 2018a; Mayer et al., 2018; Prestele et al., 2018; Sova et al., 2018; Gonzalez-Sanchez et al., 2019; 42 Lunduka et al., 2019; McFadden et al., 2019; Shah and Wu, 2019; TerAvest et al., 2019; Adams et al., 2020; 43 Aryal et al., 2020a; Debie, 2020; Mutuku et al., 2020; Somasundaram et al., 2020; Du et al., 2021). Despite 44 higher initial costs in some cases, the economic feasibility of improved cropland management is high 45 through improved productivity, higher net-returns, reduced input costs (Aryal, 2020 #6850}(Mottaleb et al., 46 2017; Keil et al., 2019; Lunduka et al., 2019; McFadden et al., 2019; Parihar et al., 2020). Self-efficacy is 47 shown to be the most important predictor in technical and non-technical adaptation behaviour (Zobeidi et al., 48 2021), while subsidies, extension services, training, commercial custom-hire services and strong social 49 connections such as farmer networks are among the factors supporting adoption among farmers (Section 50 8.5.2.3) (Aryal et al., 2015a; Aryal et al., 2015b; Kannan and Ramappa, 2017; Bedeke et al., 2019; Acevedo 51 et al., 2020). In some regions and for some practices, technological feasibility is constrained by cost, and 52 inadequate information and technical know-how on particular practices and their benefits and tradeoffs, 53 indicating medium feasibility (Khatri-Chhetri et al., 2016; Bhatta et al., 2017; Dougill et al., 2017; Kannan 54 and Ramappa, 2017; Aryal et al., 2018a; Sova et al., 2018; Findlater et al., 2019). Delays between actions 55 and tangible benefits can reduce public and private acceptability and uptake of improved cropland 56 management practices (e.g. (Dougill et al., 2017) in Malawi). | 3259 - 325 | Prot-Adapt-Mitig- | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 43 44 In Australia, climate change has been implicated in: drought-induced canopy dieback across a range of forest 45 and woodland types due to decades of declining rainfall in the southwestern hotspot (H133); fires in the 46 palaeo-endemic pencil pine forests (Tasmania H142); declines in vertebrates in the Australian Wet Tropics 47 World Heritage Area, which overlaps with the eastern part of the Northern Australia hotspot (H131), related 48 to warming and increased length of the dry season; and declines in grass and increases in shrubs in the 49 Bogong High Plains (high confidence) (Hoffmann et al., 2019). The Australian Alps have seen increased 50 species diversity following retreat of the snow line (Slatyer, 2010), replacement of long-lived trees by short- 51 lived shrubs following multiple wildfires (Zylstra, 2018), and changing ecological interactions due to 52 climate-related snow loss, drought and fires (high confidence) (Hoffmann et al., 2019). While warming is 53 allowing mangroves to expand their range in coastal hotspots of Asia and Australia (Ward et al., 2016; 54 Hughes et al., 2019a), drought and associated salinity stress has killed mangroves in northern Australia 55 hotspots (Chapter 11, Babcock et al., 2019). | 3307 - 3307 | | | |
| IPCC_AR6_WGII_Full_Report | 53 54 Range expansions out of the Nansei Shoto (H231) hotspot south of Japan led to the replacement of temperate 55 kelp forests by tropical coral and herbivorous fishes on Japanese coasts (Kumagai et al., 2018). The Yellow 56 Sea (H230) is one of the most exploited marine hotspots, with decreasing ecosystem services compounded ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Cross-Chapter Paper 1 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP1-27 Total pages: 47 1 by climate change but low confidence for climate change contributing substantially to ecological degradation 2 (Wang et al., 2016; Song and Duan, 2019). | 3318 - 3319 | | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | Actions Terrestrial Freshwater Marine Protect biodiversity hotspots Protect native forests, bush, and grasslands Stop pollution and sedimentation into streams, rivers, ponds, lakes Ban seabed trawling and dredging Control introduction and spread of invasive species and pests Increase connectivity Use riverbank and hedgerow corridors to connect protected native habitats Already connected Reduce habitat and species loss outside protected areas to add species dispersal (corridors) Outside biodiversity hotspots Environmentally sustainable agriculture, tourism, and other land and freshwater uses Environmentally sustainable aquaculture, fisheries, tourism Restoration and recovery Actively rehabilitate old mines, quarries and industrial lands Stabilise riverbanks. | 3323 - 332 | Prot-Adapt-Mitig- | | |

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| IPCC_AR6_WGII_Full_Report | 19 20 Coastal C&S within these geomorphological categories are further distinguished according to higher or 21 lower rates of urban growth and inequality – which can be estimated through population growth from 22 national census data, or areal extent of urban development (CEIC); as well as relative urban inequalities 23 estimated by Gini Coefficient data and urban-rural poverty rates (OECD, 2018; OECD, 2020). Combining 24 geomorphological and socio-economic data accounts for urban-rural interconnections and differences; with 25 levels of capital generation, diversity of economic functions and human development indices having 26 previously been used to discern cultural, economic, administrative and political differences between cities 27 and their hinterland (Blackburn et al., 2019; Rocle et al., 2020). For instance, the ecological, cultural and 28 economic footprint of tertiary sectors e.g., coastal tourism associated with the Australian Great Barrier Reef 29 stretches far beyond the nearest onshore settlement of Cairns (Bohnet and Pert, 2010; Brodie and Pearson, 30 2016). | 3345 - 3345 | | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 30 31 32 Overall, interactions between climatic and non-climatic drivers of coastal change are increasing the 33 frequency and intensity of many coastal hazards, with settlement archetypes and the wider coastal zone 34 subject to escalating risk (high confidence) (Figure CCP2.2; Table SMCCP2.1 for examples of selected 35 coastal C&S). Risks can vary markedly between different archetypes. C&S sited on deltaic and estuarine 36 coasts face additional risks of pluvial flooding compared to open coasts; while greater vulnerabilities arise in 37 coastal settlements with higher inequalities. | 3347 - 334 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 25 26 There is high confidence about regionally differentiated but considerable global sectoral impacts in coastal 27 C&S arising from exposure to hazards. Tangible impacts include damage, loss of life, loss of livelihoods, 28 especially fisheries and tourism (Tessler et al., 2015; Avelino et al., 2018; Hoegh-Guldberg et al., 2018; 29 Seekamp et al., 2019; Arabadzhyan et al., 2020); negative impacts on health and wellbeing, especially under 30 extreme events (McIver et al., 2016; Bakkensen and Mendelsohn, 2019; Bindoff et al., 2019; Pugatch, 2019); 31 and involuntary displacement and migration (Hauer, 2017; Davis et al., 2018; Neef et al., 2018; Boas et al., 32 2019; McLeman et al., 2021). Intangible impacts include psychological impacts due to extreme events, such 33 as heat-waves, flooding, droughts, and tropical cyclones; heightened inequality in coastal archetypes with 34 systematic gender/ethnicity/structural vulnerabilities; and loss of things of personal or cultural value, and 35 sense of place or connection, including existential risk of the demise of nations due to submergence (Allison 36 and Bassett, 2015; Barnett, 2017; Schmutter et al., 2017; Weir et al., 2017; Farbotko et al., 2020; Hauer et 37 al., 2020; Hoffmann et al., 2020; Bell et al., 2021). Impacts extend beyond the coastal zone, for example 38 disruption to ports and supply chains, with major geopolitical and economic ramifications from the C&S to 39 global scale (very high confidence) (Becker et al., 2018; Camus et al., 2019; Christodoulou et al., 2019; 40 Walsh et al., 2019; Hanson and Nicholls, 2020; Yang and Ge, 2020; Izaguirre et al., 2021; León-Mateos et 41 al., 2021; Ribeiro et al., 2021). | 3348 - 334 | Impact | INTANBILE | |

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| IPCC_AR6_WGII_Full_Report | 3 4 There is high confidence that loss of coastal ecosystem services will increase risks to all coastal C&S 5 archetypes that include reduced provisioning of materials and food (e.g., wood, fishery habitat) (Kok et al., 6 2021), amelioration of coastal hazards (e.g., attenuation of storm surges, waves, and containing erosion) 7 (Section 2.3.2.3; Godfroy et al., 2019; Schoutens et al., 2019; Zhu et al., 2020b), climate change mitigation 8 (through carbon sequestration) (Macreadie et al., 2017; Rovai et al., 2018; Ward, 2020), water quality 9 regulation (nutrient, pollutant and sediment retention and cycling) (Wilson et al., 2018; Zhao et al., 2018), 10 and recreation and tourism (Pueyo-Ros et al., 2018). | 3349 - 334 | ʼrot-Adapt-Mitig-Impa‹ | | |
| IPCC_AR6_WGII_Full_Report | 35 36 Retreat can effectively reduce the exposure of urban residents to coastal hazards and provide opportunity for 37 re-establishment of ecosystems services (very high confidence) (Song et al., 2018; Carey, 2020; Hindsley 38 and Yoskowitz, 2020; Lincke et al., 2020; Lincke and Hinkel, 2021). But there is high confidence that it can 39 sever cultural ties to the coast (Reimann et al., 2018) and can lead to negative and inequitable socio- 40 economic effects for resettled communities if not planned and implemented in ways that are inclusive, just 41 and address cultural, place-attachment and livelihood considerations (Ajibade, 2019; Adger et al., 2020; 42 Carey, 2020; Jain et al., 2021; Johnson et al., 2021), and the rights and practices of Indigenous People 43 (Nakashima et al., 2018; Ristroph, 2019; Mohamed Shaffril et al., 2020). If planned well ahead and aligned 44 with social goals, pathways to managed retreat can achieve positive outcomes and provide opportunities for 45 transformation of coastal C&S (Haasnoot et al., 2021a; Mach and Siders, 2021). There is medium confidence 46 that the availability of suitable and affordable land, and appropriate financing, is a major bottleneck for 47 planned relocation (Alexander et al., 2012; Ong et al., 2016; Hino et al., 2017; Fisher and Goodliffe, 2019; 48 Hanna et al., 2019; Buser, 2020; Doberstein et al., 2020), particularly in very dense mega-urban areas 49 (Ajibade, 2019) and crowded small islands (Neise and Revilla Diez, 2019; Weber et al., 2019; Kool et al., 50 2020; Lincke et al., 2020) 51 52 CCP2.3.6 Adaptation Pathways 53 54 No single adaptation intervention comprehensively addresses coastal risks and enables CRD. An adaptation 55 pathways approach can facilitate long-term thinking, foresee maladaptive consequences and lock-ins, and 56 address dynamic risk in the face of relentless and potentially high SLR; and frame adaptation as a series of 57 manageable steps over time (Cross-Chapter Box DEEP in Chapter 17; Figure CCP2.4; Haasnoot et al. | 3353 - 335 | ʼrot-Adapt-Mitig-Impa‹ | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 25 26 Even where BCR is high, finance may be inaccessible as it is challenging to convert the long-term benefits 27 of adaptation into the revenue streams that may be needed to initially finance adaptation investments (Hinkel 28 et al., 2018). For example, in Ho Chi Minh City, Vietnam, despite high BCR, high costs of flood protection 29 (US$1.4-2.6 billion) have prevented such adaptation measures from being implemented (Hinkel et al., 2018; 30 Cao et al., 2021). Moreover, drawing from places as distinct as small communities in Fiji (Neef et al., 2018) 31 and Belize (Karlsson and Hovelsrud, 2015), and megacities like New York City and Shanghai (Oppenheimer 32 et al., 2019), BCR provides only a limited view and consideration of feasibility, effectiveness, efficiency, 33 equity, culture, politics and power, and attachment to place, is more likely to foster CRD (high confidence). | 3357 - 335 | ʼrot-Adapt-Mitig-Impa‹ | | |
| IPCC_AR6_WGII_Full_Report | 41 42 Inclusive decision-making arrangements can enable participation, local ownership, and further equity in 43 crafting coastal adaptation plans and policies (Chu et al., 2016). Inclusion of diverse stakeholders can help 44 improve awareness of adaptation needs; help to bridge existing social inequalities in decision-making about 45 adaption needs, options and outcomes; close the gap between formal and informal institutions, and engage 46 Indigenous forms of decision-making, which often associate climate risks with livelihood, housing, and 47 employment stressors (Ziervogel et al., 2016; Fayombo, 2020). For example, research from Pacific Island 48 States (Nunn et al., 2017) and coastal Arctic zones (Romero Manrique et al., 2018) highlight the need to 49 engage with Indigenous environmental knowledge. Case studies from Indonesia, Philippines, and Timor- 50 Leste show that IKLK and customary laws can support environmental awareness, strengthen social cohesion, 51 and help communities to better respond to climate impacts (Hiwasaki et al., 2015). Research from coastal 52 Cambodia shows that inclusive governance arrangements can target empowerment of the most vulnerable 53 groups to facilitate better adaptation behavior and mainstream adaption knowledge through both formal and 54 informal education at the community level (Ung et al., 2016). | 3358 - 335 | ʼrot-Adapt-Mitig-Impact | | INDG |

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| IPCC_AR6_WGII_Full_Report | Cross-scale and cross-domain coordination: Coordination - Collaborative projects involve state and non-state actors Seychelles (0.1mill; open coast, small island): Cross-sectoral and institutional collaboration to improve use of limited financial resources; and ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Cross Chapter Paper 2 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP2-22 Total pages: 42 - Multi-lateral agreements, e.g., between neighbouring countries, coastal regions and C&S - Connect people, organizations and communities through boundary spanning organizations - Leadership by central actors with capable teams is key - Mobilise the capabilities of communities and non-state actors - Address policy inconsistencies and clarify roles and responsibilities - Secure national and regional resources to support local efforts - Use measures to promote interaction, deliberation and coordination to manage spill-over effects - Strengthen linkages between formal (e.g., regulatory) and informal (e.g., traditions and rituals) institutions, e.g., through information sharing - Use spatial coordination mechanisms, e.g., land-use planning, to translate national and regional provisions into local competencies community-based and ecosystem-based adaptation to bridge adaptation and mitigation and improve coordination. | 3360 - 336 | 'rot-Adapt-Mitig-Impa | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | - Account for local history, culture and politics through engagement, experimentation and innovation - Generate socio-economic, livelihood and climate�development co-benefits - Leverage national and trans-national community and local authority networks Cape Town, South Africa (4.6mill; mixed): Capable local leaders collaborate with researchers in municipality-initiated community-based adaptation. Translating plans into action challenging given 'everyday' vulnerability exacerbated by climate change impacts. | 3361 - 336 | 'rot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | 10 11 These climate risks at the coast can also be magnified by compounding and cascading effects due to non- 12 climate drivers directly affecting vulnerable peri- and ex-urban areas inland. These risks include disruption 13 to transport supply chains and energy infrastructure from airports and power plants sited along coastal areas, 14 as occurred in New York City, USA, during Hurricane Sandy in 2012. The impacts can be felt around the 15 world through globalized economic and geopolitical linkages, e.g., through maritime trade and port linkages. | 3364 - 336 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 16 17 For open coasts, settlements on low-lying small island states and the Arctic are especially vulnerable to 18 climate change, and sea level rise impacts in particular, well before 2100. While the economic risks may not 19 compare to the scale of those faced in coastal megacities with high per capita GDP, the existential risks to 20 some nations and an array of distinctive livelihoods, cultural heritage, and ways-of-life in these settlements 21 are great, even with modest sea level rise. | 3364 - 336 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 6 7 Coastal risks and impacts such as floods, loss of fisheries or tourism, or salinization of groundwater, require 8 people to change behaviour to adapt, such as diversifying livelihoods or moving away from low-lying areas. | 3365 - 336 | 'rot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | 33 34 Coastal C&S are on the frontline of the climate change challenge. They are the interface of three 35 interconnected realities. First, they are critical nodes of global trade, economic activity and coast-dependent 36 livelihoods, all of which are highly and increasingly exposed to climate- and ocean-driven hazards (FAQ 37 CCP2.1). Second, coastal C&S are also sites where some of the most pressing development challenges are at 38 play (e.g., trade-offs between expanding critical built infrastructure while protecting coastal ecosystems, 39 high economic growth coupled with high inequality in some coastal megacities). Third, coastal C&S are also 40 centres of innovation and creativity, thus presenting a tremendous opportunity for climate action through a 41 range of infrastructural, nature-based, institutional, and behavioural solutions (FAQ CCP2.2). Given these 42 three realities of high climate change risks, rapid but contested and unequal development trajectories, and 43 high potential for innovative climate action, C&S are key to charting pathways for Climate Resilient 44 Development. | 3365 - 336 | 'rot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | 10 11 Where are we now: Observed impacts and adaptation responses 12 13 Deserts and semi-arid areas have already been affected by climate change, with some areas 14 experiencing increases in aridity. Mixed trends of decreases and increases in vegetation productivity 15 have been observed, depending on the time period, geographic region, detection methods used and vegetation type under consideration (high confidence1 16 ). These changes have had varying and location- 17 specific impacts on biodiversity, and have altered ecosystem carbon balance, water availability and the 18 provision of ecosystem services (high confidence). There is no evidence, however, of a global trend in 19 dryland expansion based on analyses of vegetation patterns, precipitation and soil moisture, with 20 overall, more greening than drying in drylands since the 1980s (medium confidence). Deserts and semi- 21 arid areas host unique biodiversity, rich cultural heritage and provide globally valuable ecosystem services. | 3383 - 338 | 'rot-Adapt-Mitig-Impact | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 22 They are also highly vulnerable to climate change. The vitality of natural ecosystems in arid and semi-arid 23 regions greatly depends on water availability, as they are highly sensitive to changes in precipitation and 24 potential evapotranspiration {3.1.2; 3.2.1}, as well as to land management practices. Multiple lines of 25 evidence from 1920-2015 indicate that surface warming of 1.2ºC-1.3ºC over global drylands (Section 1.1.1) 26 exceeded the 0.8ºC-1.0ºC warming over humid lands. From 1982 to 2015, unsustainable land use and 27 climate change combined caused desertification of 6% of the global dryland area, while 41% showed 28 significant increases in vegetation productivity (greening) and 53% of the area had no notable change, 29 although greening rates are slowing or declining in some locations. Greening may cause biodiversity loss and 30 ecosystem service degradation in relation to livelihood systems {3.2.2}. Observed trends in deserts and semi- 31 arid areas have led to varying impacts on flora, fauna, soil, nutrient cycling, the carbon cycle and water 32 resources. Ecological changes in dryland ecosystems detected and attributed primarily to climate change 33 include tree mortality and losses of mesic tree species at specific sites in the African Sahel particularly 34 during the droughts of the 1970s and 80s, and in North Africa from 1970 to 2007 (CCP4.3.2); and losses of 35 bird species in the Mojave Desert of North America from 1908 to 2016 (CCP4.3.2). In contrast, growth in 36 herbaceous vegetation production has increased in some drylands since the 1980s. Widespread woody 37 encroachment has occurred in many shrublands and savannas in Africa, Australia, North America and South 38 America, due to a combination of land use change, changes in rainfall, fire suppression, and CO2 fertilization 39 {3.2.1, 3.2.2} which, together with unsustainable management, alters biodiversity and reduces ecosystem 40 services such as water availability and grazing potential. | 3383 - 338 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 40 Deserts and semi-arid areas have a rich cultural heritage, Indigenous knowledge, and local knowledge which 41 enrich and influence sustainability and land use globally. Growing research evidence and experience 42 highlight the necessary features of an enabling environment for dryland adaptation (Section 8.5.2). Key 43 enablers include supportive policies, institutions and governance approaches that strengthen the adaptive 44 capacities of dryland farmers, pastoralists and other dryland resource users (high confidence), addressing 45 drivers (proximate and underlying) as well as symptoms of desertification. For instance, the skills and 46 capacities held by the mobile and adaptive approach of pastoralists may provide lessons for society at large 47 in adapting to climate change and dealing with increased uncertainty. Such a policy would stand in contrast 48 to previous attempts at settling pastoralists. There is a persistent gap in terms of scaling-up already known 49 good practices, combining nature-based, land-based, and ecosystem-based approaches that facilitate 50 sustainable land management, with contextually appropriate and responsible governance systems (e.g., 51 including those supporting communal land tenure arrangements and Indigenous knowledge) (medium 2 In this Report, the following terms have been used to indicate the assessed likelihood of an outcome or a result: Virtually certain 99–100% probability, Very likely 90–100%, Likely 66–100%, About as likely as not 33–66%, Unlikely 0–33%, Very unlikely 0–10%, and Exceptionally unlikely 0–1%. Additional terms (Extremely likely: 95– 100%, More likely than not >50–100%, and Extremely unlikely 0–5%) may also be used when appropriate. Assessed likelihood is typeset in italics, e.g., very likely). This Report also uses the term 'likely range' to indicate that the assessed likelihood of an outcome lies within the 17-83% probability range ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Cross-Chapter Paper 3 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP3-4 Total pages: 53 1 confidence). Land based adaptations can help manage dryland changes including sand and dust storms and 2 desertification (high confidence), while technological options linked to water management draw from both 3 traditional practices and new innovations. Adequate financing and investment is required to harness multiple 4 benefits for managing the impacts of climate change and desertification whilst accelerating progress | 3384 - 338 | 'rot-Adapt-Mitig-Impact | | INDG |

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| IPCC_AR6_WGII_Full_Report | 6 7 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Cross-Chapter Paper 3 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP3-5 Total pages: 53 1 CCP3.1 Introduction 2 3 CCP3.1.1 Concepts, Definitions and Scope 4 5 Deserts and semi-arid areas are in 'drylands', which comprise hyper-arid, arid, semi-arid and dry sub-humid 6 areas (Figure CCP3.1). Drylands cover about 45-47% of the global land area (Prăvălie, 2016; Koutroulis, 7 2019) and are home to about 3 billion people residing primarily in semi-arid and dry sub-humid areas (van 8 der Esch et al., 2017). Drylands host unique, rich biodiversity (Maestre et al., 2015) and provide important 9 ecosystem services (Bidak et al., 2015; Lu et al., 2018), while dryland people have a rich cultural and 10 historical heritage. Rural human populations are growing in some Mediterranean and tropical drylands, while 11 many are rapidly urbanizing (Guengant Jean-Pierre, 2003; Tabutin and Schoumaker, 2004; Denis and 12 Moriconi-Ebrard, 2009), with varying impacts on ecosystem services and adaptive capacities. In recent 13 decades, 6% of global megacities have been established in arid areas and 2% in hyper-arid desert areas 14 (Cherlet et al., 2018), with many of these areas suffering from severe water security challenges (Stringer et 15 al., 2021). Dryland inhabitants in many developing countries are also experiencing poverty (Section 16 16.1.4.3), hunger, poor health, land degradation, and economic and political marginalisation (Mbow et al., 17 2019; Mirzabaev et al., 2019), which sometimes limits their access to common pool resources. These 18 challenges, together with a weak enabling environment, threaten opportunities to adapt to climate change. | 3385 - 338 | Prot-Adapt-Mitig-Impact | | |
| IPCC_AR6_WGII_Full_Report | 47 48 Drylands yield important opportunities for adapting to and mitigating climate change. They offer abundant 49 solar energy which could support mitigation efforts, opportunities for cultural and nature-based tourism, rich 50 plant biodiversity in some areas (e.g. Namibia), and extensive Indigenous knowledge and experience of 51 adapting to dynamic climates (Christie et al., 2014; Stringer et al., 2017), e.g. across West Asia and North 52 Africa (Louhaichi and Tastad, 2010; Hussein, 2011). Improved understanding of challenges and 53 opportunities in drylands can be achieved by transdisciplinary, multi-scale and inter-sectoral approaches 54 encompassing links between physical, biological and socioeconomic, and institutional systems (Reynolds et 55 al., 2007; Stringer et al., 2017). | 3386 - 338 | Prot-Adapt-Mitig- | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 4 5 CCP3.2.1.5 Tree Death and Woody Cover Decline 6 7 Field measurements have also detected tree mortality and loss of mesic tree species at some Sahel sites 8 during drought periods (Gonzalez et al., 2012; Kusserow, 2017; Brandt et al., 2018; Ibrahim et al., 2018; 9 Trichon et al., 2018; Zwarts et al., 2018; Bernardino et al., 2020; Zida et al., 2020) and a reduction of mesic 10 species in favour of drought-tolerant species (high confidence) (Hänke et al., 2016; Kusserow, 2017; Ibrahim 11 et al., 2018; Trichon et al., 2018; Dendoncker et al., 2020; Zida et al., 2020b), with attribution to climate 12 change (Gonzalez et al., 2012). Furthermore, vegetation productivity per unit of rainfall showed a net decline 13 of 4% in the period 2000-2015 across drylands globally, with the greatest net declines in Africa (16%) and 14 Asia (33%) (Abel et al., 2021), but with location-specific increases in vegetation-rainfall sensitivity, e.g. in 15 southern and eastern Africa and parts of the Sahel. Furthermore, NDVI declines were reported across the 16 Sahel from 1999 to 2015 (Yuan et al., 2019; Zida et al., 2020a). However, field site monitoring showed a 17 strong regeneration of the decimated woody populations except on shallow soil where the runoff system had 18 evolved towards a web of gullies (Hiernaux et al., 2009a; Trichon et al., 2018; Wendling et al., 2019) . | 3390 - 3390 | | | |
| IPCC_AR6_WGII_Full_Report | 19 20 Other site-specific impacts include tree mortality in south-western Morocco (Le Polain de Waroux and 21 Lambin, 2012), mortality of Austrocedrus and Nothofagus forests in the dry Patagonia forest-steppe 22 (Rodríguez-Catón et al., 2019), and a tree range contraction of Aloidendron dichotmum in Southern Africa 23 (Foden et al., 2007b). In Morocco, tree mortality was most highly correlated to an increase in aridity, 24 measured by the Palmer Drought Severity Index (PDSI), which showed a statistically significant increase 25 since 1900 due to climate change (Dai et al., 2004; Esper et al., 2007; Dai, 2011). | 3390 - 339 | Impact | | |

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| IPCC_AR6_WGII_Full_Report | 54 55 Qualitative case studies tend to frame conflict and migration within a larger political, economic and 56 historical context. A number of studies from African drylands find that land dispossession is a key driver of 57 both migration and conflict resulting from large-scale resource extraction or land encroachment often ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Cross-Chapter Paper 3 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP3-15 Total pages: 53 1 associated with processes of elite capture and marginalization (Benjaminsen and Ba, 2009; Benjaminsen et 2 al., 2009; Cross, 2013; Glick Schiller, 2015; Nyantakyi-Frimpong and Bezner Kerr, 2017; Obeng-Odoom, 3 2017; Bergius et al., 2020). By undermining livelihoods, exacerbating poverty, and setting rural population 4 groups adrift, land dispossession in the Sahel may lead to increased migration to urban areas, to rural sites of 5 non-farm employment (e.g. mines) (Chevrillon-Guibert et al., 2019) or out of the country. In addition, it may 6 lead to other types of reactions including violent resistance (Oliver-Smith, 2010; Cavanagh and 7 Benjaminsen, 2015; Hall et al., 2015) as already seen in the Sahel in terms of the emergence of jihadist 8 armed groups (Benjaminsen and Ba, 2019). Major drivers of the current crisis in Mali include decades of 9 bureaucratic mismanagement and widespread corruption, the spill-over of jihadist groups from Algeria after 10 the civil war there in the 1990s and the current civil war in Libya. Climate change has played a marginal role 11 as a driver of conflicts in the Sahel (Benjaminsen et al., 2012; Benjaminsen and Hiernaux, 2019) but has 12 potential to exacerbate the situation in the future with regards to migration and conflict (Owain and Maslin, 13 2018). | 3395 - 3396 | | | |
| IPCC_AR6_WGII_Full_Report | 31 32 The relative contribution of albedo and evapotranspiration to regional trends in surface temperature 33 (Charney, 1975) remains unresolved, and may be determined by different mechanisms in different systems, 34 depending on site-specific conditions such as snow coverage, vegetation and soil moisture (Yu et al., 2017). | 3398 - 3398 | | | |
| IPCC_AR6_WGII_Full_Report | Livestock, human�ignited fires Medium Iknayan and Beissinger (2018); Riddell et al. (2019) Decline of desert tortoise (Gopherus agassizii) population 90% from 1993 to 2012 at one site in the Mojave Decreased rainfall Lovich et al. (2014) Reduced perennial vegetation cover, including trees and cacti, in the Mojave and Sonoran deserts of the southwestern United States Increased temperature, decreased rainfall, wildfire Land use change, invasive plant species High Defalco et al. (2010); Munson et al. (2016b); Conver et al. | 3405 - 3405 | | | |
| IPCC_AR6_WGII_Full_Report | (2017) Arid African Sahel Woody cover increase in parts of the Sahel Increase in rainfall since the mid-1990s (compared to 1968-1993)and increased $CO_2$ Restoration planting Agroforestry High ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Cross-Chapter Paper 3 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP3-25 Total pages: 53 Increase in grass production across Sahel Increases in rainfall since the mid-1990s (compared to 1968-1993) and increased $CO_2$ Medium Hiernaux et al. (2009a); Hiernaux et al. (2009b); Dardel et al. (2014); Venter et al. (2018); Zhang et al. (2018); Brandt et al. (2019); Bernardino et al. (2020) Decline of mesic tree species at field sites across the Sahel Decreased rainfall from 1901 to 2002 increased temperature Yes. | 3405 - 3406 | | | |
| IPCC_AR6_WGII_Full_Report | Land clearing for cropland expansion, Increase pressure on wood resources (rural demography, urbanization) High Gonzalez (2001); Wezel and Lykke (2006); Maranz (2009); Gonzalez et al. (2012); Hänke et al. (2016); Kusserow (2017); Ibrahim et al. (2018); Zida et al. (2020b) Increased tree mortality at field sites across the Sahel Decreased rainfall from 1901 to 2002, increased temperature Yes. | 3406 - 3406 | | | |
| IPCC_AR6_WGII_Full_Report | Woody encroachment Medium Blaum et al. (2007); Blaum et al. (2009); Sirami and Monadjem (2012); Gray and Bond (2013); Péron and Altwegg (2015); Smit and Prins (2015) African semi�arid regions (savanna) Reduced tourism experience due to woody encroachment Woody encroachment Low Gray and Bond (2013) North American drylands – sagebrush steppes Sagebrush steppes are being invaded by non-native grasses Increase in temperature and favourable climates High Bradley et al. (2016); Hufft and Zelikova (2016); Chambers (2018) Shrub encroachment,(Prosopis glandulosa, Juniper ashei and Juniper pinchotti) is occurring in the semi-arid grasslands of the southern great plains at a rate of ~8% per decade Increasing temperature, elevated $CO_2$ and changing rainfall Fire suppression and altered grazing/browsing regimes High Caracciolo et al. (2016); Archer et al. (2017) Woody encroachment in sagebrush steppes (cold deserts) (Juniper occidentalis) at a rate of 2% per decade a) Warming and associated decline in snowpack b) Less precipitation falling as snow and an increase in the rain fraction in winter. | 3411 - 3411 | | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | FINAL DRAFT Cross-Chapter Paper 4 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP4-2 Total pages: 50 1 Executive Summary 2 3 The Mediterranean Region hosts exceptional biological diversity and socio-cultural richness 4 originating from three continents. The nature of the semi-enclosed Mediterranean Sea and the complex 5 topography imply unique physiographic and ecological features. The region has undergone continuous 6 change in human activities during several millennia, and it now hosts more than 500 million people with a 7 high concentration of urban settlements and industrial infrast`ructure close to sea level. The region is the 8 world's leading tourist destination and one of its busiest shipping routes. Climate change strongly interacts 9 with other environmental problems in the Mediterranean Basin, resulting from urbanisation, land use change, 10 overfishing, pollution, biodiversity loss and degradation of land and marine ecosystems. {CCP4.1.1} 11 12 Previous IPCC reports have never assessed the Mediterranean region as an entity – but they have 13 nevertheless shown that virtually all parts of it are vulnerable and face significant risks due to climate 14 change. Identified regional key risks include increased water scarcity (notably in the South and East) and 15 droughts (in the North), coastal risks due to flooding, erosion and saltwater intrusions, wildfire, terrestrial 16 and marine ecosystem losses, as well as risks to food production and security, human health, well-being and 17 the cultural heritage. {CCP4.1.2} 18 19 Surface temperature in the Mediterranean region is now 1.5°C above pre-industrial level, with a corresponding increase in high-temperature extreme events (high confidence1 20 ). Trends in precipitation 21 are variable across the basin (low confidence). Droughts have become more frequent and intense, 22 especially in the North Mediterranean (high confidence). The sea surface has warmed by 0.29-0.44°C 23 per decade since the early 1980s with stronger trends in the Eastern Basin. Sea level has risen by 1.4±0.2 mm yr-1 during the 20th century (2.8±0.1 mm yr-1 24 over 1993-2018) (high confidence). Ocean 25 acidity is increasing (medium confidence). {CCP4.1.3} 26 27 A growing number of observed impacts across the entire basin are now being attributed to climate 28 change, along with major roles of other forcings of environmental change (medium to high confidence). | 3434 - 343 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 29 These impacts include multiple consequences of longer and/or more intensive heat waves, droughts, floods, 30 ocean acidification and sea-level rise, such as cascading impacts on marine and terrestrial ecosystems as well 31 as on land and sea use (agriculture, forestry, fisheries, tourism, recreation etc.) and human health. | 3436 - 343 | Impact | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Cross-Chapter Paper 4 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP4-3 Total pages: 50 1 Coastal flood risks will increase in low-lying areas along 37% of the Mediterranean coastline that currently 2 host 42 million people. The number of people exposed to sea-level rise is projected to increase up to 2050, 3 especially in the Southern and Eastern Mediterranean region, and may reach up to 130% compared to present 4 in 2100 (medium confidence). Coastal settlements, world heritage sites and ecosystems are at longer-term 5 risk from sustained sea-level rise over at least the coming three centuries (high confidence). {CCP4.1.3, 6 CCP4.2, CCP4.3, SMCCP4.4} 7 8 Due to its particular combination of multiple strong climate hazards and high vulnerability, the 9 Mediterranean region is a hotspot for highly interconnected climate risks. The main economic sectors in 10 the region (agriculture, fisheries, forestry, tourism) are highly vulnerable to climatic hazards, while socio- 11 economic vulnerability is also considerable. The low-lying areas are the most vulnerable areas for coastal 12 climate-related risks (e.g. sea level rise, floods, erosion) and other consequent risks (e.g. saltwater intrusion 13 and agriculture damage) (high confidence). Climate change threatens water availability, reducing river low 14 flows and annual runoff by 5-70%, reducing hydropower capacity (high confidence). Yields of rain-fed crops 15 may decrease by 64% in some locations (high confidence). Ocean warming and acidification will impact 16 marine ecosystems, with uncertain consequences on fisheries (low confidence). Desertification will affect 17 additional areas, notably in the South and South-East (medium confidence). Burnt area of forests may 18 increase by 96-187% under 3°C, depending on fire management (low confidence). Beyond 3°C, 13-30% of 19 the Natura 2000 protected area and 15-23% of Natura 2000 sites could be lost due to climate-driven habitat 20 change (medium confidence). {CCP4.2, CCP4.3} 21 22 The adaptive capacity of ecosystems and human systems is expected to encounter hard limits due to 23 the interacting, cumulative and cascading effects of droughts, heat waves, sea-level rise, ocean 24 warming and acidification (high confidence). Coastal protection can reduce risks from sea-level rise in 25 some regions, but the costs of such interventions and their consequences for coastal ecosystems are high 26 (medium confidence) {CCP4.4.1}. There is low confidence in the feasibility of adaptation options to sea- 27 level rise beyond 2100 or for large Antarctic ice melting. {CCP4.4.5} 28 29 Progress towards achievement of the UN Sustainable Development Goals differs strongly between 30 Mediterranean sub-regions, with north-western countries having stronger resilience than southern 31 and eastern countries (high confidence). To equitably enhance regional adaptive capacity and sustainable 32 development, while safeguarding the rights of the most vulnerable people, regional cooperation can be 33 strengthened with a focus on the link between adaptation, costs and financial limitation and climate justice 34 (high confidence). Cooperative policies across multiple various sectors, involving all user groups and 35 considering all regional and sectorial differences may enhance sustainable resource use in the region (high 36 confidence). {CCP4.4.6} 37 38 Sharing and co-production of knowledge can support climate adaptation practices and enhance 39 sustainability in the Mediterranean region (medium to high confidence). Currently incomplete 40 knowledge of climate impacts and risks in the southern and eastern part of the basin hinders the 41 implementation of adaptation measures, creating a need for implementable plans with enhanced and 42 | 3436 - 343 | Prot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGII_Full_Report | 43 {CCP4.4} 44 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Cross-Chapter Paper 4 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP4-4 Total pages: 50 1 CCP4.1 Climate Change in the Mediterranean Basin 2 3 CCP4.1.1 The Mediterranean Sea, Land and People 4 5 The Mediterranean Basin, known for its exceptional environmental and socio-cultural richness, comprises the semi-enclosed Mediterranean Sea and the countries and regions bordering it3 6 , which belong to Europe, 7 Asia and Africa (Figure CCP4.1). The region has a unique historical and environmental identity (Abulafia, 8 2011), despite undeniable variations in the environment, socio-economic conditions and cultural traditions. | 3437 - 3438 | | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 34 3 By tradition, also Portugal and Jordan are considered Mediterranean countries, despite having no Mediterranean coastline ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Cross-Chapter Paper 4 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP4-5 Total pages: 50 1 With the changing climate, marine ecosystems have already undergone changes in structure, including the 2 spread of tropical species from the Atlantic Ocean and the Red Sea (high confidence) and mass mortality in 3 at least 25 invertebrate species, threatening, along with ocean acidification, marine ecosystems, including 4 seagrass meadows (Hoegh-Guldberg et al., 2014; Nurse et al., 2014; Pörtner et al., 2014; Wong et al., 2014). | 3438 - 3439 | | INTANBILE | |

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| IPCC_AR6_WGII_Full_Report | 19 20 The increasing water scarcity was found to be a significant threat to agriculture (Jiménez Cisneros et al., 21 2014; Kovats et al., 2014; Niang et al., 2014; Mrabet et al., 2020). Associated with increased extreme 22 temperatures, the Mediterranean is expected to become less attractive for tourism (Kovats et al., 2014; Nurse 23 et al., 2014; Wong et al., 2014; Dos Santos et al., 2020). Several critical risks for human health increase due 24 to climate change, including heat waves and vector-borne diseases (Kovats et al., 2014; Nurse et al., 2014; 25 Linares et al., 2020). Adaptation options have been identified for many risks (buildings, water management, 26 coastal protection etc.) (Murray et al., 2012; Revi et al., 2014; Wong et al., 2014). There are synergies 27 between adaptation and mitigation, e.g. renewable energies or nature-based solutions focused on the 28 conservation and restoration of ecosystems (Nurse et al., 2014; Hoegh-Guldberg et al., 2018; Vafeidis et al., 29 2020). | 3439 - 343 | 'rot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | 30 31 32 CCP4.2 Vulnerability of Mediterranean Countries to Climate Change 33 34 CCP4.2.1 The Specific Vulnerability of Mediterranean countries 35 36 The Mediterranean region is predominantly vulnerable to the impacts of warming, notably prolonged and 37 stronger heat waves, and increased drought in an already dry climate, and risk of coastal flooding (Section 38 CCP4.1). Southern and Eastern countries are generally more vulnerable than countries in the north. Several 39 countries (Tunisia, Algeria and Libya) are below the water scarcity threshold set by the Food and Agriculture 40 Organization of the United Nations (FAO), others (Morocco) are close to the threshold for severe water 41 stress. Uncertainties regarding the timing, duration, intensity and interval between extreme climatic events 42 put some sectors such as agriculture and tourism at particular risk in the Mediterranean region (Section 43 CCP4.3; Kallis, 2008; Kutiel, 2019). | 3443 - 344 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 56 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Cross-Chapter Paper 4 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP4-11 Total pages: 50 1 The Mediterranean region accounts for one third of global tourism with 330 million tourists in 2016 (Tovar- 2 Sánchez et al., 2019). Before the COVID-19 crisis, international tourist arrivals were assumed to increase by 3 60% between 2015 and 2030 and reach 500 million then. In 2015, tourism supported 15% of the total 4 employment in the region (Randone et al., 2017). France, Spain, Italy and Greece are the top tourist 5 destinations (UNWTO, 2016), but the highest growth was in Turkey, Croatia and Albania during 1995-2015 6 (MGI, 2017). The tourism industry is vulnerable to climate change, particularly in low income countries 7 (Dogru et al., 2016; Dogru et al., 2019). Coastal tourism in the region generates 300 billion USD annually 8 followed by marine tourism (110 billion USD) (Radhouane, 2013; Randone et al., 2017). | 3444 - 3445 | | | |
| IPCC_AR6_WGII_Full_Report | 47 48 Combined with storm surges, sea-level rise may disrupt Mediterranean port operations (Sánchez-Arcilla et 49 al., 2016; Sierra et al., 2016), with risks depending on adaptation, physical protection measures and basin 50 depth. Risks for deep ports are more limited (Sierra et al., 2017), while low-depth small harbours, common 51 in the Mediterranean, could be significantly affected (Sierra et al., 2016). Sea-level rise may enhance sandy 52 beach erosion and thereby impact recreation and tourism (Bitan and Zviely, 2018; Rizzetto, 2020), 53 magnifying coastal degradation and pollution (Enríquez et al., 2017; Gössling et al., 2018). | 3447 - 344 | 'rot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | 54 55 CCP4.3.3 Inland Ecosystems 56 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Cross-Chapter Paper 4 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP4-14 Total pages: 50 1 Beyond 3°C GWL, 13-30% of the Mediterranean Natura 2000 protected area and 15 to 23% of Natura 2000 2 sites are projected to change towards more arid ecosystem types (Barredo et al., 2016). Biodiversity and 3 ecosystem services would be exposed to degradation of wetland hydrology, which could affect 19-32% of 4 localities under a 1.5 to 2°C GWL (48-73% under higher warming), particularly in Spain, Portugal, Morocco 5 and Algeria (Lefebvre et al., 2019) and a substantial shrinking of terrestrial and freshwater ecosystem 6 habitats, in particular in Mediterranean islands (Chapters 2 and 4; CCP1). | 3447 - 344 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | 9 Increasing heat waves, combined with drought and land-use change, reduce fuel moisture, thereby increasing 10 fire risk, extending the duration of fire seasons and increasing the likelihood of large, severe fires (high 11 confidence) (EEA, 2017; Lozano et al., 2017; Peñuelas et al., 2017; Varela et al., 2019). Fires impact 12 vegetation recovery after abandonment, thus transforming landscapes (González-De Vega et al., 2016). At 13 warming levels of 1.5°C, 2°C and 3°C, burnt area in Mediterranean Europe could increase by 40-54%, 62- 14 87% and 96-187%, respectively (Turco et al., 2018b), although changes are highly site-dependant and also 15 affected by management (Caon et al., 2014; Wu et al., 2015; Parra and Moreno, 2018; Brotons and Duane, 16 2019; Hinojosa et al., 2019). | 3448 - 344 | Impact | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 9 10 CCP4.3.5 Human Health and Cultural Heritage 11 12 Warming is projected to impact human health, mostly through increased intensity, frequency and duration of 13 heat waves (high confidence) (Guerreiro et al., 2018; Jacob et al., 2018; Rohat et al., 2019; Smid et al., 14 2019). Under current socio-economic conditions, 53-93 million more people could be exposed to high or 15 very high heat stress in northern Mediterranean by 2050 (Gasparrini et al., 2017; Rohat et al., 2019) and 16 heat-related excess mortality could increase by more than 6-fold above 3°C GWL (Gasparrini et al., 2017; 17 Rohat et al., 2019). In MENA countries, the mortality risk of the elderly in 2100 could be 8-20 times higher 18 under RCP8.5 compared to 1951-2005, and still 3-7 times higher under RCP4.5 (Ahmadalipour and 19 Moradkhani, 2018). Deaths attributable to high temperatures in the northern Mediterranean could increase by 20 18-20,000 in 2050 (50,000 in 2100) under RCP8.5 (1.4 and 2.6 times lower under RCP4.5) (Kendrovski et 21 al., 2017). | 3450 - 345 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 39 40 Many studies project a decrease of climatic comfort for tourism in the Mediterranean by 2071 to 2100, 41 particularly during summer (Grillakis et al., 2016; Jacob et al., 2018; Braki and Anagnostopoulou, 2019). | 3450 - 3450 | | | |
| IPCC_AR6_WGII_Full_Report | 42 There is adaptive potential in the extension of the period with favourable climatic conditions for urban 43 tourism in Mediterranean cities (Scott et al., 2016). Water scarcity may create additional constraints for 44 tourism (Köberl et al., 2016). | 3450 - 345 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | 45 46 Cultural heritage sites in the region face risks from coastal flooding, with 37 out of 49 cultural World 47 Heritage Sites today facing risk from a 100-year flood, and 42 of them from coastal erosion (Reimann et al., 48 2018b). Sea-level rise will increase these risks (high confidence) (Lionello, 2012; Rizzi et al., 2017; Reimann 49 et al., 2018b; Ravanelli et al., 2019; Tagliapietra et al., 2019). By 2100, 47 of the 49 UNESCO sites are 50 projected to be at risk from coastal flooding or erosion (Reimann et al., 2018b). Beyond 2100, sea levels are 51 committed to rise further and represent an existential threat for the high number of coastal cultural heritage 52 located in the Mediterranean (AR6 WGI Chapter 9; Chapter 13; Cross-Chapter Box SLR in Chapter 3; 53 Marzeion and Levermann, 2014). | 3450 - 345 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 6 7 8 9 Figure CCP4.7: Key risks in the Mediterranean and their location for SSP5-RCP8.5 by 2100 across the Mediterranean 10 region for SSP5-RCP8.5 by 2100 (Sections CCP4.3.2-6 and Table SMCCP4.2a & b for details). Risks to world cultural 11 heritage sites from flooding or erosion due to sea-level rise in multiple locations (section CCP4.3.5) and Mediterranean 12 river deltas are hotspots of vulnerability to climate change (Section CCP4.3.2). The population exposed to risks is 13 mapped for an SSP5-8.5 pathway. Adaptation can reduce these risks (Section CCP4.4) (based on: Reimann et al., 14 2018a; Reimann et al., 2018b; Wolff et al., 2018). | 3451 - 345 | 'rot-Adapt-Mitig-Impact | | |
| IPCC_AR6_WGII_Full_Report | 15 16 17 18 Figure CCP4.8: Summary of key risks for the Mediterranean (Sections CCP4.3.2-8 and Supplementary Tables 19 SMCCP4.2a-h for details). Coastal risks include one burning ember displaying additional risks due to climate change as 20 specific GWL are exceeded (Coastal risks), and one burning ember describing additional risks due to committed sea- 21 level rise at timescales of centuries and millennia for long living infrastructure and cultural heritage (AR6 WGI Chapter 22 9; Marzeion et al., 2014; Marzeion and Levermann, 2014; Clark et al., 2016; see SMCCP4.2h). | 3451 - 345 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 4 5 Technical options include the reduction of losses in water distribution networks for drinking water and 6 irrigation (Burak and Margat, 2016; Fader et al., 2016), desalinization, often combined with generation of 7 electricity (Papanicolas et al., 2016; Bonanos et al., 2017; Jones et al., 2019), artificial recharge of 8 groundwater and subterranean dams (Djuma et al., 2017; De Giglio et al., 2018; Missimer and Maliva, 2018; 9 Baena-Ruiz et al., 2020), and waste water reuse (Kalavrouziotis et al., 2015; Barba-Suñol et al., 2018; 10 Cherfouh et al., 2018). On the demand side, options include changing diet and water consumption patterns 11 (Blas et al., 2016; Gul et al., 2017; Blas et al., 2018) and enhancing water use efficiency in the tourism and 12 food sector (Hadjikakou et al., 2013; Moresi, 2014). | 3453 - 3453 | | | |
| IPCC_AR6_WGII_Full_Report | 42 43 44 Table CCP4.2: Transformative adaptation and mitigation options for climate resilient sustainable development in the 45 Mediterranean Basin Code Sector Transformative option References T1 Energy, transport and tourism National plans and regulations to decarbonise fuel sources and electricity grids on the supply side, for reducing energy demand and increasing efficiency and converting transport systems from fossil fuels to electricity UNEP/MAP (2016); Bastianin et al. (2017); EEA (2018a); EEA (2018b); OME (2018); CMI and EC (2019); EEA (2019); Sachs et al. (2019); EC, (2020); Simionescu et al. (2020) T2 Energy Deployment of large-scale Mediterranean transboundary renewable energy infrastructures and interconnections. Transboundary energy market integration schemes. | 3454 - 345 | Prot-Adapt-Mitig- | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 35 36 In general, increasing temperatures and more intensive heatwaves in the basin threaten human well-being, 37 economic activities and also many ecosystems on land and in the ocean. Extreme rainfall events, which 38 despite the lower total rainfall are expected to increase in intensity and frequency in some regions, generate 39 significant risks for infrastructure and people through flash floods. Warming also affects the ocean and its 40 ecosystems, jointly with acidification caused by atmospheric carbon dioxide. Finally, sea-level rise, currently 41 accelerating as a consequence of global ice loss, threatens coastal ecosystems, historical sites and a growing 42 human population. | 3459 - 345 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 5 6 7 Risks associated with projected climate change are particularly high for people and ecosystems in the 8 Mediterranean Basin due to the unique combination of many factors, including: 9 i) a large and growing urban population exposed to heat waves, with limited access to air conditioning, 10 ii) a large and growing number of people living in settlements impacted by rising sea level, 11 iii) important and increasing water shortages, experienced by 180 million people today already, 12 iv) growing demand for water by agriculture for on irrigation, 13 v) high economic dependency on tourism, which is likely to suffer from increasing heat but also from the 14 consequences of international emission reduction policies on aviation and cruise-ship travel, 15 vi) loss of ecosystems in the ocean, wetlands, rivers and also uplands, many of which are already 16 endangered by unsustainable practices (e.g. overfishing, land use change). | 3460 - 346 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 30 Sea level in the Mediterranean has been rising by only 1.4 mm yr-1 31 during the 20th century, more recently by 2.4±0.5mm yr−1 32 from 1993 to 2012, and it is bound to continue rising in the future. Future rates are projected 33 to be similar to the global mean (within an uncertainty of 10-20 cm), potentially reaching 1.1 m or more 34 around 2100 in the event of 3°C of global warming (Figure FAQ-CCP4.2; SMCCP4.4). Due to the ongoing 35 ice loss in Greenland and Antarctica, this trend is expected to continue in coming centuries. Sea-level rise 36 already impacts extreme coastal waters around the Mediterranean and it is projected to increase coastal 37 flooding, erosion and salinization risks. These impacts would affect agriculture, fisheries and aquaculture, 38 urban development, port operations, tourism, cultural sites, and many coastal ecosystems. | 3460 - 346 | Impact | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 39 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Cross-Chapter Paper 4 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP4-27 Total pages: 50 1 Most of the Mediterranean Sea is a micro-tidal environment, which means that the difference between 2 regular high and mean water levels (astronomical tides) is very small. Storm surges and waves can produce 3 coastal floods that persist for several hours, causing particularly large impacts on sandy coasts and eventually 4 also on coastal infrastructure. Mediterranean coasts are also characterized by narrow sandy beaches that are 5 highly valuable for coastal ecosystems and tourism. These beaches are projected to be increasingly affected 6 by erosion and eventually disappear where sedimentary stocks are small. | 3460 - 346 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 7 8 Overall, Mediterranean low-lying areas of significant width occur along 37% of the coastline and currently 9 host 42 million inhabitants. The coastal population growth projected until 2050 mostly occurs in southern 10 Mediterranean countries, with Egypt, Libya, Morocco and Tunisia being the most exposed countries to 11 future sea-level rise. The area at risk also hosts 49 cultural World Heritage Sites, including the city of Venice 12 and the early Christian monuments of Ravenna. The Mediterranean also includes areas subjected to sinking 13 of the land (subsidence), including the eastern Nile delta (Egypt) and the Thessaloniki flood plain (Greece), where local relative sea-level rise can exceed 1 cm yr-1 14 today. | 3461 - 346 | Impact | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Cross-Chapter Paper 5 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP5-4 Total pages: 63 1 land-use change and management also play a role (medium confidence). {CCP5.2.3; CCP5.2.5; Table 2 CCP5.2; SROCC Section 2.3.1.3.2; SROCC Section 2.3.7} 3 4 While contributing to poverty reduction in some mountain regions, there is limited evidence of 5 adaptations effectively contributing to remediating the underlying social determinants of vulnerability 6 such as gender and ethnicity (medium confidence). Exposure and vulnerability exacerbate the negative 7 effects of climate impacts on livelihoods, and intertwines with power imbalances, gender and other 8 inequalities (medium confidence). {CCP5.2.7; CCP5.3.2.2} 9 10 Observed changes in seasonality (timing and extent) are negatively affecting mountain winter tourism 11 and recreation (high confidence), and variably affect tourism and recreation activities in other seasons 12 (medium confidence). For winter activities such as skiing, diminishing snow at lower elevations has 13 challenged their operating conditions (medium confidence), increasing the demand for and dependence on 14 snow management measures such as snow-making (high confidence). Climate-induced hazards are 15 negatively affecting some climbing, mountaineering, and hiking routes (medium confidence). In some 16 regions, options to change routes or shift seasons to reduce hazard exposure have been employed as 17 adaptation strategies, with variable outcomes (medium confidence). In some cases, higher temperatures and 18 extreme heatwave conditions at lower elevations have made some mountain destinations more appealing, 19 increasing the potential for summer visitation demand (medium confidence). {CCP5.2.5; Table CCP5.2; 20 SROCC Ch2.3.5} 21 22 Climate-related hazards, such as flash floods and landslides, have contributed to an increase in 23 disasters affecting a growing number of people in mountain regions and further downstream (high 24 confidence). The resulting number of disasters has increased, however there is limited evidence that this is 25 due to changes in the underlying hazard processes, pointing mainly to increasing levels of exposure (medium 26 confidence). {CCP5.2.6; CCP5.2.7; CCP5.3.2.1}. | 3487 - 348 | 'rot-Adapt-Mitig-Impa | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 27 28 Adaptation responses to climate-driven impacts in mountain regions vary significantly in terms of 29 goals and priorities, scope, depth and speed of implementation, governance and modes of decision- 30 making, and the extent of financial and other resources to implement them (high confidence). Observed 31 adaptation responses in mountains are largely incremental and mainly focus on early warning systems and 32 the diversification of livelihood strategies in smallholder agriculture, pastoralism, and tourism. However, 33 there is limited evidence of the feasibility and long-term effectiveness of these measures to address climate- 34 related impacts and related losses and damages, including in cities and settlements experiencing changing 35 demographics. {CCP5.2.4; CCP5.2.7.2} 36 37 Projected impacts, key risks and limits to adaptation in mountains 38 39 Increasing temperatures will continue to induce changes in mountain regions throughout the 21st 40 century, with expected negative consequences for mountain cryosphere, biodiversity, ecosystem 41 services and human wellbeing (very high confidence). Many low elevation and small glaciers around the world will lose most of their total mass at 1.5° 42 C GWL (high confidence). A large majority of endemic 43 mountain species will be at risk of extinction; regions heavily relying on glacier- and snow-melt for 44 irrigation will face erratic water supply and increased food insecurity, whereas agriculture in some regions 45 might see positive changes. Damages and losses from water related hazards such as floods and landslides are 46 projected to increase considerably between 1.5 and 3° GWL. {CCP5.3.1} 47 48 Projected changes in hazards, such as floods and landslides, as well as changes in the water cycle, will 49 lead to severe risk consequences for people, infrastructure and the economy in many mountain regions 50 (high confidence). These risks will be more pervasive and also increase more rapidly in South and Central 51 Asia and Northwestern South America. However, nearly all mountain regions will face at least moderate and 52 some regions even high risks at around 2°C GWL (medium confidence). {CCP5.3.2.1, CCP5.3.2.2; 16.B.4} 53 54 There is an increasing risk of local and global species extinctions where they are not able to move to 55 higher elevations or other cooler locations (high confidence), with risks from extreme events such as 56 wildfire potentially exacerbating those risks (medium confidence). The topographic variation in 57 mountains may mean that some species can survive in cooler microclimates with aspect as well as elevation. | 3488 - 348 | 'rot-Adapt-Mitig-Impa | | |

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| IPCC_AR6_WGII_Full_Report | 10 However, there is limited evidence on the magnitude of the consequences. {CCP5.3.2.4; 16.5.2.1; 16.5.2.3.7} 11 12 Options for future adaptation and climate resilient sustainable development in mountains 13 14 The current pace, depth and scope of adaptation is insufficient to address future risks in mountain 15 regions, particularly at higher warming levels (high confidence). While the incremental nature of most 16 implemented adaptations will not be sufficient to reduce severe risk consequences, options exist which offer 17 practical and timely prospects to address risks before limits to adaptation are reached or exceeded. Reducing 18 climate risks will depend on addressing the root causes of vulnerability, which include poverty, 19 marginalization, and inequitable gender dynamics (high confidence). {CCP5.4.1, Figure CCP5.7: CCP5.4.2, 20 Cross-Chapter Box DEEP in Chapter 17; Cross-Chapter Box LOSS in Chapter 17; 17.3, 17.6} 21 22 Adaptation decision-making processes that engage with and incorporate people's concerns and values 23 and address multiple risks are more robust than those with a narrow focus on single risks (medium 24 confidence). Risk management strategies that better integrate the adaptation needs of all affected sectors, 25 account for different risk perceptions and build on multiple and diverse knowledge systems, including 26 Indigenous knowledge and local knowledge, are important enabling conditions to reduce risk severity 27 (medium confidence). {CCP5.2.6, CCP5.4.2; 17.3; 17.4; Cross-Chapter Box PROGRESS in Chapter 17; 28 Cross-Chapter Box DEEP in Chapter 17} 29 30 Regional cooperation and transboundary governance in mountain regions, supported by multi-scale 31 knowledge networks and monitoring programmes, enable long-term adaptation actions where risks 32 transcend boundaries and jurisdictions (medium confidence). Collectively, they show potential to form 33 an important component of the adaptation solution space in mountains. There are increasing calls for more 34 ambitious climate action in mountains, providing impetus for stronger cooperation within and across 35 mountain regions, and downstream areas (medium confidence). {CCP5.4.2; CCP5.4.3} 36 With warming above 1.5o 37 C, the need for adaptation to address key risks in mountains becomes 38 increasingly urgent (high confidence). Pathways and system transitions that strengthen climate-resilient 39 sustainable mountain development are starting to receive attention, but current levels of resourcing are 40 substantially insufficient to support timely action. {CCP5.4.2; CCP5.4.3; CCP5.5; 18.1; 18.2} 41 42 43 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Cross-Chapter Paper 5 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP5-6 Total pages: 63 1 CCP5.1 Point of Departure 2 3 Mountains are an extensive and significant typological region (Section 1.3.3 and AR6 Glossary) in the 4 context of climate change and sustainable development, with a large population directly or indirectly 5 depending on mountains. These are areas of high biological and cultural diversity that provide vital goods 6 and services – such as water, food, energy, minerals, medicinal plants, tourism and recreation, and aesthetic 7 and spiritual values – to people living in and around these mountain regions and in downstream areas. | 3489 - 349 | 'rot-Adapt-Mitig-Impact | | INDG |
| IPCC_AR6_WGII_Full_Report | 8 Mountain regions are hotspots of climate related losses in, for example, ecosystems, landscapes, culture, and 9 habitability, and while mountain people are adaptive, resourceful, and independent, they live in highly fragile 10 environments and in some regions under challenging socioeconomic circumstances that enhance their 11 vulnerability to climate change (Alfthan et al., 2018). | 3490 - 349 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | 30 31 Changes in mountain biodiversity and ecosystems have a wide range of impacts on ecosystem services and 32 effects on people. Some mountain ecosystems, particularly those with peatlands or forests are important 33 carbon stores and climate change presents a risk to these in some locations (Dwire et al., 2018) (Sections 34 2.4.3.8; 2.4.4.4; 2.4.4.5). Palomo (2017) identified a wide range of threats to the lives, livelihoods and 35 culture of mountain people as a consequence of the impacts of climate change on ecosystems. However, 36 impacts are very heterogeneous between locations, even within the same region and ecosystem type (for 37 example mountain forests in Europe; Mina et al. (2017) and are not necessarily all negative. As well as 38 changes in services, other impacts on humans from a changing climate may be mediated through species and 39 ecosystems, for example changes in vector distribution shifting disease incidence into higher elevation areas 40 (Escobar et al., 2016). | 3493 - 349 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 18 19 Water plays a fundamental role in climate change adaptation in mountains. A majority of documented 20 adaptation efforts in mountain regions address water-related aspects (precipitation variability and extremes, 21 including drought, water availability, floods) (McDowell et al., 2019; McDowell et al., 2020) (high 22 confidence). This is a robust finding across different mountain regions and adaptation project and program 23 types, and also in line with findings for cryosphere change related adaptation as reported in SROCC (Hock et 24 al., 2019). Water also plays a role for adaptation in other sectors such as agriculture, disaster management 25 and tourism and recreation (McDowell et al., 2019). There is high confidence that water conservation efforts, 26 also including restoration and protection of particularly vulnerable areas (e.g., wetlands), and increase of 27 efficiency in water use, are robust, low-regret adaptation measures. | 3496 - 349 | Prot-Adapt-Mitig- | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 48 49 Ecosystem products are vital to support the livelihoods and economic prospects for communities living in 50 and around mountains (Figure CCP5.3). For instance, collection and trade of caterpillar fungus contributed 51 to 53.3 - 64.5% annual household cash income in Nepal (Shrestha and Bawa, 2014; Shrestha et al., 2019); 52 40-80% in Bhutan (Thapa et al., 2018); 60-78% in Uttarakhand, India (Laha et al., 2018; Yadav et al., 2019) 53 (Section 5.7.1). Livelihood support from ecosystem products in Southern Malawi region (Pullanikkatil et al., 54 2020), south-western Ethiopian mountains (Nischalke et al., 2017) and Southern China (Min et al., 2017), 55 Himalayan mountains (Nepal et al., 2018), South Africa (Ngwenya et al., 2019) is reported. Additionally, the 56 sacredness of mountains in different religions and cultures is widely acknowledged (Ceruti, 2019; Benedetti 57 et al., 2021). | 3498 - 3498 | | | |
| IPCC_AR6_WGII_Full_Report | 25 26 CCP5.2.5 Mountain Communities, Livelihoods, Health and Wellbeing 27 28 People living in and around mountain regions strongly depend on the ecosystem functions, services and 29 resources available in these areas for their livelihoods, health and wellbeing. Overall, subsistence agriculture 30 and livestock remain key sources of livelihood in many mountain regions (FAO, 2019), with non-agricultural 31 income sources such as remittances, small businesses, medicinal plants, wage labour and tourism also 32 contributing to these economies (Montanari and Koutsoyiannis, 2014; Palomo, 2017; Minta et al., 2018). | 3501 - 3501 | | | |
| IPCC_AR6_WGII_Full_Report | 33 This section provides an illustrative overview of key reported observed impacts and adaptation responses to 34 climate change on mountain communities (Table CCP5.1), and livelihood activities and economic sectors 35 such as agriculture and pastoralism, and tourism and recreation (Table CCP5.2), reported since AR5. | 3501 - 350 | rot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | Furu and Van (2013); Section CCP5.4.1 1 2 3 Table CCP5.2: Overview of key observed impacts and adaptation on select livelihood activities and economic sectors 4 – mountain agriculture and pastoralism; and tourism and recreation. | 3503 - 350 | rot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | Reid (2016); Grêt-Regamey and Weibel (2020); Cross-Chapter Box NATURAL in Chapter 2 Tourism and Recreation Impacts • Since SROCC, the literature on climate change impacts on ski winter tourism has remained dominated by studies focused on future climate change impacts and projected risks due to decreasing seasonal snow reliability (see CCP5.3.1), most relevant when considering snow management and in particular snowmaking. | 3504 - 350 | Impact | | |
| IPCC_AR6_WGII_Full_Report | Hock et al. (2019); Mourey et al. (2019); Mourey et al. (2020) • Higher temperatures and extreme heatwave conditions at lower elevations have made some mountain destinations more appealing for human comfort, increasing the potential summer visitation demand and opportunities for tourism and recreation in mountains, such as in the European Alps and the Catalan Pyrenees (medium confidence). However, there is limited evidence reported for similar trends in mountain regions outside of Europe. | 3504 - 3504 | | | |
| IPCC_AR6_WGII_Full_Report | (2019a); Juschten et al. (2019b) Responses and adaptation • Diversification of tourism activities to non-snow activities is reported as an adaptation approach to maintain economic viability in some winter ski areas, partly due to the high cost of running snowmaking infrastructure in winter e.g. in the Pyrenees (Europe) and Australian Alps. | 3504 - 350 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | Hock et al. (2019); Mourey et al. (2019); Mourey et al. (2020) ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Cross-Chapter Paper 5 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP5-21 Total pages: 63 Overview of key observed impacts and adaptation on select livelihood activities and economic sectors References and relevant AR6 WGII Sections • In some cases, such as in Bolivia, Peru, and New Zealand, and more recently reported in the French Alps, 'last chance' tourism has increased the appeal of some mountain destinations, resulting in visitation demand to witness the effects of climate change on iconic mountain landscape features such as glaciers. | 3504 - 350 | rot-Adapt-Mitig-Impa | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 28 29 Climate change impacts have been documented in mountains of all continents. A wide range of human and 30 natural systems have been affected by climate change to date, including the cryosphere, water resources, 31 terrestrial and aquatic ecosystems, agriculture, tourism, energy production, infrastructure, health and life, 32 migration, disasters and community and cultural values. The confidence levels for detection of impacts are 33 generally in the range of medium to high. The contribution of climate change to the detected impact varies 34 depending on the affected system, and climatic and non-climatic drivers. The highest levels of confidence for 35 attribution of detected impacts to anthropogenic climate change is assigned to the cryosphere. More 36 generally, those impacts are more strongly driven by increasing temperatures and show higher confidence for 37 attribution than those impacts mainly driven by precipitation changes. The level of contribution of climate 38 change to observed impacts is predominantly medium or high, indicating the high sensitivity of natural and 39 human systems in mountains to climate change. Furthermore, the vast majority of detected impacts imply 40 negative impacts on natural and human systems (high confidence). | 3506 - 350 | Impact | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 47 48 Furthermore, the science of attributing negative impacts of climate change to anthropogenic emissions or 49 even individual polluters is becoming increasingly important for climate litigation (Marjanac et al., 2017; 50 McCormick et al., 2017; Otto et al., 2017; Setzer and Vanhala, 2019) and there is emerging evidence that 51 mountains are becoming sites of litigation cases, with cases for instance in Peru, Colombia, and India 52 (UNEP, 2017). Recent studies put litigation cases such as the Lliuya vs RWE case on risk of glacier lake 53 floods in Peru in a broader context of differentiated responsibilities and justice (Huggel et al., 2020b). | 3506 - 350 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 20 21 Since SROCC (Hock et al., 2019), several new studies have addressed projected impacts of future climate 22 change on snow reliability in ski resorts, complementing previous findings or bridging existing knowledge 23 gaps for winter tourism. This includes, in particular, new studies for China (An et al., 2019; Fang et al., 24 2019), showing that average ski seasons are projected to shorten (-4 to -61% for RCP4.5; -6 to -79% RCP8.5 25 in the 2050s) along with increases in snowmaking water demand (27 to 51% for RCP4.5; 46 to 80% for 26 RCP8.5 in the 2050s), with large differences across the country. Changes in future snow reliability are 27 projected across Europe at the national or pan-European scale (Demiroglu et al., 2019; Steiger and Scott, 28 2020; Morin et al., 2021), highlighting strong contrasts at the local (across ski resorts size and/or elevation 29 range, or local social or environmental context) and continental scales. Higher latitude and high elevation 30 locations generally exhibit delayed declines in snow reliability compared to lower latitude and lower- 31 elevation locations (high confidence), consistent with assessment conclusions reached in SROCC (Hock et 32 al., 2019). In general, climate change impacts and risks to ski tourism are found to be spatially 33 heterogeneous, within and across local and international markets, with potential for significant disruptions to 34 related socio-economic sectors due to a growing mismatch between ski area supply and skier demand in the 35 coming decades (Fang et al., 2019; Hock et al., 2019; Steiger et al., 2020a) (high confidence). These 36 disruptions are plausible, even though a fraction of current ski resorts could technically be able to operate 37 under comparatively favourable locations (elevation, latitude) and operating models (business models, socio- 38 cultural assets and conditions, governance) (Steiger et al., 2020b). | 3510 - 351 | Impact | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 46 Projected changes in ice and snow-melt, as well as seasonal increases in extreme rainfall and permafrost 47 thaw, will favour chain reactions and cascading processes which can have devastating downstream effects 48 well beyond the site of the original event (Cui and Jia, 2015; Beniston et al., 2018; Terzi et al., 2019; Vaidya 49 et al., 2019; Shugar et al., 2021) (high confidence). The incidence of disasters is projected to increase in the 50 future due to some hazards becoming more pervasive, with an increase in the exposure of people and 51 infrastructure with future environmental and socio-economic changes either contributing to reduce or 52 enhance these disaster risks (Klein et al., 2019b) (medium confidence). | 3510 - 351 | Impact | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 42 43 CCP5.3.2.4 KR4: Risk of Intangible Losses and the Loss of Cultural Values 44 45 The risk of intangible losses and loss of cultural values is associated with the decline of ice and snow cover 46 and temperature increase, as well as the increase in intangible harm from hazards such as floods and 47 droughts (high agreement, medium evidence) (Diemberger et al., 2015; Jurt et al., 2015; Vuille et al., 2018; 48 Tschakert et al., 2019; Vander Naald, 2020). Losses are intangible because they characterise aspects which 49 are difficult to quantify, i.e. loss of identity, loss of self-reliance, loss of rituals and traditions and place 50 attachment (Allison, 2015; Baul and McDonald, 2015; Motschmann et al., 2020a; Schneiderbauer et al., 51 2021). A global systematic analysis of case studies shows that this risk is more prevalent in the Andes, the 52 Himalaya and the Alps (Tschakert et al., 2019). Often mentioned across studies is the loss of intrinsic 53 memories and culture related to changes in world heritage landscapes and iconic sites (Jurt et al., 2015; 54 Sherry et al., 2018; Bosson et al., 2019). Changes in the hazard landscapes are also reported to contribute to 55 the loss of peace of mind and loss of well-being (Diemberger et al., 2015). Overall, there is limited evidence 56 but medium agreement that the risk of intangible losses and the loss of cultural identity will rapidly increase 57 and that consequences will go from reversible damage to irreversible losses (Tschakert et al., 2019). | 3514 - 351 | Impact | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 36 37 Mountains are the home of many cultures and diverse Indigenous knowledge and local knowledge (systems), 38 which can and do provide strong support for place-based integrated adaptation and mitigation strategies 39 (Merino et al., 2019). Indigenous knowledge and local knowledge reinforce community adaptive capacity, 40 yet governance structures and processes, including the deliberate design and implementation of climate 41 policy, can constrain that capacity from being realised (Hill, 2013; McDowell et al., 2014; Wyborn et al., 42 2015; Klepp and Chavez-Rodriguez, 2018; Lavorel et al., 2019) (high confidence). Communities, 43 particularly poor and remote mountain communities, are vulnerable to climate change and there is a need for 44 capacity building in research, policy development and implementation for pursuing climate resilient 45 development (Manton and Stevenson, 2014). Climatic stressors and socio-economic changes are changing 46 traditional genderscapes in mountain communities (Goodrich et al., 2019). There is increasing evidence on 47 the roles that gendered diversity in knowledge, institutions, and everyday practices can play in addressing 48 barriers and creating opportunities for achieving resilience, adaptive capacity and sustainability in societies 49 (Gioli et al., 2014; Ravera et al., 2016; Su et al., 2017; Udas et al., 2018; Goodrich et al., 2019; Sujakhu et 50 al., 2019). | 3518 - 351 | Prot-Adapt-Mitig- | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 26 27 The availability of freshwater is a function of water supply and water demand, with the latter being 28 determined by sectors such as agriculture, energy, industry, or domestic use, as well as by competition 29 between these sectors. Formal and informal water extraction and use prevail, and competition includes issues 30 of inequalities, and power relations and asymmetry. Consequently, the effects of climate change on water 31 resources, people and ecosystems are strongly modulated and often exacerbated by socio-economic 32 development and related water resource management. For example, increasing frequency and intensity of 33 droughts in the European Alps, combined with decline and seasonal shifts of river runoff from snow and 34 glacier melt, is expected to result in growing competition between different sectors, such as hydropower, 35 agriculture, and tourism. Similar developments are projected or have already been observed in many other 36 mountain regions. This situation calls for strengthening and improving negotiation formats for water 37 management that are transparent, equal, and socially and environmentally just. Management of water 38 demand and strategies that entail multiple uses of water will become increasingly important in this context. | 3522 - 352 | Impact | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 9 This is of relevance in mountains, where disaster risk is influenced by population growth, induced 10 displacements, land-use changes and inefficient water distribution systems. For example, current trends 11 suggest that more people are settling in exposed locations, with more infrastructure being built and activities 12 such as tourism and recreation being promoted, exacerbating this exposure. | 3523 - 352 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 42 43 Mountain regions cover about a quarter of the Earth's land surface, scattered around the globe and may 44 support a wide range of climates within short horizontal distances. Mountains have experienced above- 45 average warming, and this trend is expected to continue. Mountains provide a variety of goods for people, 46 are home to many Indigenous Peoples and are attractive for tourism and recreational activities. Mountain 47 regions support many different ecosystems and some are very species rich. Mountain regions can be vast and 48 diverse, and climate change and impacts on ecosystems vary greatly depending on location. | 3523 - 352 | Impact | | INDG |
| IPCC_AR6_WGII_Full_Report | 9 Other processes creating stresses on mountain ecosystems are direct human impacts, such as the influence of 10 grazing, tourism, air pollution and nitrogen deposition on alpine vegetation. In some cases, these impacts can 11 be so large on the goods and services provided by alpine ecosystems, that they can overshadow the effects of 12 climate change or exacerbate its effects. | 3524 - 352 | Impact | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 16 Treelines have moved up in the last 30-100 years in many mountain regions, including e.g. Andes, Urals and 17 Altai. At the same time, since the 1990s, treelines responses in different parts of the Himalaya have been 18 highly variable, in some places advancing upslope, in others demonstrating little change, and in others 19 moving downward. This can be explained by site-specific complex interactions of the positive effect of 20 warming on tree growth, drought stress, change in snow precipitation, land-use change, especially grazing, 21 and other factors. Treelines are affected by land use and management around the globe and changing land- 22 use practices can supersede climate change effects in some mountain regions. An upward shift in elevation 23 of bioclimatic zones, decreases in area of the highest elevation zones, and an expansion of the lower zones 24 can be expected by mid-century, for examples in regions such as the Himalaya. | 3524 - 352 | Impact | | |
| IPCC_AR6_WGII Full Report | 29 The appeal and feasibility of mountains for tourism and recreation activities are also affected by climate 30 change. | 3524 - 3524 | | | |
| IPCC_AR6_WGII_Full_Report | 8 9 The polar regions, notably the Arctic and maritime Antarctic, are experiencing impacts from climate 10 change at magnitudes and rates that are among the highest in the world, and will become profoundly 11 different in the near-term future (by 2050) under all warming scenarios (high confidence). In the 12 Arctic, accelerated sea-ice loss (particularly during summer), increased permafrost thaw and extreme high 13 temperatures have substantially impacted marine, freshwater and terrestrial sociological-ecological systems 14 (very high confidence). Multiple physical, ecological and societal elements of polar regions are approaching 15 a level of change potentially irreversible for hundreds of years, if not millennia (high confidence). Evidence 16 of borealization of terrestrial and marine systems is emerging (high confidence), and cascading impacts are 17 on-going and widespread yet challenging to quantify fully due to complexity and lags in ecological 18 expression of change. Loss of multi-year sea-ice and the occurrence of a seasonally ice-free Arctic Ocean by 19 the middle of this century will result in substantial range contraction, if not the disappearance of several 20 Arctic fish, crab, bird and marine mammal species, including possible extinction of seals and polar bears in 21 certain regions (high confidence). In the Arctic, permafrost thaw and snowfall decrease lead to profound 22 hydrological changes, an overall greening of the tundra and regional browning of tundra and boreal forests 23 (high confidence). (CCP6.1; Table CCP6.1; Table CCP6.2; CCP6.2.1; CCP6.2.2; Table CCP6.5) 24 25 Contractions of the polar climate zones lead to distribution shifts and changes in food webs, induce 26 declines in many species (medium confidence) with impacts on subsistence harvests and commercial 27 fisheries, and threaten global dependence on polar regions for substantial marine food production 28 (high confidence). Climate change has induced food web changes resulting in population declines in polar 29 seabirds, including penguins, and marine and terrestrial mammals (high confidence). Globally and regionally 30 important harvested fish and invertebrate species are also contracting ranges and declining productivity, 31 including Pacific cod, salmon, snow and king crab in the Arctic and krill in the Antarctic (medium 32 confidence), with implications for global food systems (high confidence). (Table CCP6.2; CCP6.2.1; 33 CCP6.2.3; Table CCP6.3; Table CCP6.4) 34 35 Loss of sea-ice is rapidly expanding opportunities, but also increasing risks for shipping and other 36 economic industries in polar regions (very high confidence). Reduced sea-ice enables greater access to 37 high-latitudinal seas for industries, such as fisheries, shipping, tourism (very high confidence) and Arctic 38 maritime trade and resource extraction (medium confidence). Navigational risks have grown due to 39 increasingly mobile multi-year ice, poor hydrographic charting in newly open areas, and limited weather, 40 water, ice, and climate data and services (high confidence). Cascading risks from polar shipping growth 41 include increased air emissions, underwater noise pollution, disruption to subsistence hunting and cultural 42 activities in the Arctic (high confidence) and potential for invasive marine species and geopolitical tensions 43 (medium confidence). (Table CCP6.3; CCP6.2.4; Box CCP6.1; Table CCP6.5; Table CCP6.6) 44 45 Increased permafrost thaw and flooding will disrupt economically important transportation and 46 supply-chain infrastructure to remote Arctic settlements (high confidence), increasing risks to 47 economies, Arctic tourism and tourism to cultural heritage sites (medium confidence). Arctic permafrost 48 thaw is projected to impact most infrastructure by the middle of this century, impacting millions of people 49 and their economies, and costing billions in damages (high confidence). (CCP6.2.3; CCP6.2.4; Box CCP6.1; 50 CCP6.2.5; | 3549 - 354 | Impact | | |
| IPCC_AR6_WGII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Cross-Chapter Paper 6 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP6-3 Total pages: 66 1 Climate change increasingly threatens many facets of Arctic livelihoods, culture, identity, health and 2 security, particularly for Indigenous Peoples (very high confidence). It has negatively impacted mental 3 health and increased risks of injury, food insecurity and foodborne and waterborne disease, with risks 4 amplified for those reliant on the environment for subsistence, livelihoods and identity (high confidence). | 3549 - 355 | Impact | | INDG |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 5 Permafrost thaw, sea-level rise and reduced sea-ice protection have already damaged or destroyed many 6 cultural heritage sites in some Arctic regions (very high confidence) and are projected to continue across all 7 Arctic regions (very high confidence). (CCP6.2.3; Table CCP6.3; CCP6.2.4; CCP6.2.5; CCP6.2.6; Figure 8 CCP6.3; Box CCP6.2; CCP6.3.1; Table CCP6.5; Table CCP6.6) 9 10 Adaptation 11 12 Adaptations to manage climate change impacts and risks in polar regions are urgently needed (very 13 high confidence), but implementation is uneven (high confidence), limits to adaptation are high and 14 maladaptation is probable (high confidence). | 3550 - 355 | ʼrot-Adapt-Mitig-Impact | | |
| IPCC_AR6_WGII_Full_Report | 47 48 Development of robust pathways for climate resilience in the Arctic can be accelerated by adaptation 49 strategies and governance that reflect local conditions, cultures and adaptive capacities of 50 communities and sectors (high confidence). Effectiveness of adaptation strategies will be enhanced by 51 accounting for the geographic, climatic, ecological and cultural uniqueness of the polar regions (medium 52 confidence). Colonialism can inhibit the development of robust climate adaptation strategies, and exacerbate 53 climate risks (very high confidence). Inclusive decision-making in establishing climate adaptations can foster 54 resilience, reflect the unique environmental, cultural, and economic imperatives of the region and support 55 both market-based and sharing economies (high confidence). (Box CCP6.2; Table CCP6.6; CCP6.3.2; 56 CCP6.4) 57 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Cross-Chapter Paper 6 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP6-4 Total pages: 66 1 Indigenous self-determination in managing climate change impacts, adaptations, and solutions can 2 accelerate effective robust climate-resilient development pathways in the Arctic (very high confidence). | 3550 - 355 | ʼrot-Adapt-Mitig-Impa | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 10 11 These changes are causing a suite of direct and cascading risks for all polar ecosystems with larger effects to 12 date in the Arctic than the Antarctic (high confidence), due to larger and regionally more consistent physical 13 changes (Figure CCP6.2, Table CCP6.1; Chapter 3) (Meredith et al., 2019; Ranasinghe et al., 2021). In the 14 Arctic, these changes affect every sector of society, impacting its 4,000,000 inhabitants, including 400,000 15 Indigenous People. The Antarctic has no permanent human settlements; however, many nations conduct 16 field research, operate seasonal and permanent stations and have an interest in the management of the region 17 (Hughes et al., 2018; Grant et al., 2021). During summer, when Antarctic science, tourism and fishery 18 activities are greatest, 4,400 people live there, whereas only 1,100 people live there over winter (Meredith et 19 al., 2019). Although adaptation is occurring in polar regions, it is uneven and sporadic and does not meet the 20 risks posed by future climate change. Indigenous knowledge-based solutions, inclusive ecosystem-based 21 policies and integrated technologies demonstrate the potential to effectively address climate change impacts 22 across scales and sectors; yet implementation barriers remain (CCP6.4.1). | 3552 - 355 | ʼrot-Adapt-Mitig-Impa | | INDG |
| IPCC_AR6_WGII_Full_Report | 40 Climate change continues to alter vegetation and attendant biodiversity, with divergent regional trends across 41 the Arctic due to disparities in local conditions and changes in growing seasons (Zhu et al., 2016; Taylor et 42 al., 2020). Warming facilitates woody vegetation growth in northeastern Siberia, western Alaska, and 43 northern Quebec (Song et al., 2018; García Criado et al., 2020), as well as a northward expansion of shrub 44 vegetation and sub-Arctic and boreal species (Davidson et al., 2020). | 3562 - 3562 | | | |
| IPCC_AR6_WGII_Full_Report | 45 46 Further evidence shows that warming and changes to the Arctic hydrologic cycle increase the risk of wildfire 47 (medium confidence) (Mustonen and Shadrin, 2021). Both the frequency of and the area burned by wildfires 48 during recent years are unprecedented compared to the last 10,000 years (high confidence) (Meredith et al., 49 2019; Irannezhad et al., 2020). Fire risk levels are projected to increase across most tundra and boreal 50 regions, and interactions between climate and shifting vegetation (Song et al., 2018) will influence future fire 51 intensity and frequency (medium confidence) (Curtis et al., 2018). | 3562 - 356 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 44 45 46 CCP6.2.3 Food, Fiber, and other Ecosystem Products 47 48 Food and fiber production underpins regional identities, cultures, and communities of practice and place in 49 polar regions, are vital to local and distant economies (Table CCP6.4) and they represent for fisheries a 50 critical source of global nutrition and food security (Hicks et al., 2019). Since SROCC, there is further 51 evidence that climate change alterations of polar ecosystems increasingly challenge production of, and 52 access to, sufficient, healthy, and nutritious food, posing risks to future food and nutritional security within 53 and beyond polar regions (high confidence). | 3563 - 356 | Impact | | |
| IPCC_AR6_WGII_Full_Report | (Furberg et al., 2011; Uboni et al., 2020; Mustonen and Shadrin, 2021) Sea-ice; winds; visibility Loss of multiyear “mother ice”, declines in seasonal sea-ice thickness and stability, as well as changes in winds and visibility have impacted the availability of, and access to, subsistence resources (high confidence) and have increased interactions between coastal communities and shipping, tourism and commercial fisheries, which directly impact human safety and well-being in Arctic communities (high confidence). | 3564 - 356 | Impact | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 24 25 Large-scale commercial fisheries are expected to continue to operate in polar regions (high confidence) 26 (Barange et al., 2018; Cavanagh et al., 2021; Grant et al., 2021), and will shift poleward (high confidence) 27 toward geopolitical and management boundaries (high confidence) (CCP6.3.2.3; Table CCP6.6). Warming 28 and climate impacts will continue to impact transboundary stocks and increase the potential for conflict in 29 fisheries management (Pinsky et al., 2018; Mendenhall et al., 2020; Palacios-Abrantes et al., 2020; Sumaila 30 et al., 2020). Increased distances from ports to redistributed fishing grounds, as well as increased frequency 31 of storms and other extreme events are expected to increase risks and costs for fishery operations (medium 32 confidence) and impact shore-based infrastructure and emergency response services (CCP6.2.4). Observed 33 and expected increases in mobile ice combined with abrupt wind can create major hazards for fish operators 34 in Antarctica and the Arctic, with consequences to human safety and total revenue (Dawson and et al., 2017; 35 Barber et al., 2018; Grant et al., 2021). There will be increased demand for new port infrastructure across the 36 Arctic (high confidence); new ports have already been proposed for the northern Bering Sea, and small craft 37 harbour investments are being considered across Arctic Canada and Greenland. Ecosystem-based 38 management, increasing diversity and flexibility in harvest portfolios, access to high-resolution ecological 39 forecasts and projections, and climate-informed advice will promote adaptation and climate resilience in 40 fisheries (Dawson and et al., 2017; Brooks et al., 2018; Karp et al., 2019; Hollowed et al., 2020). Coupling 41 adaptation measures with global carbon mitigation strategies substantially decreases climate change risks to 42 polar fisheries (very high confidence) (CCP6.3). | 3566 - 356 | Prot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGII_Full_Report | (Piñones and Fedorov, 2016; Klein et al., 2018) 1 2 3 CCP6.2.4 Economic Activities 4 5 Climate change presents significant risks to economic activities in the polar regions (very high confidence) 6 and simultaneously enables development possibilities for fisheries (CCP6.2.3.3), agriculture (CCP6.2.3.2), 7 the sharing and subsistence economy (CCP6.2.3.1) (SMCCP6.2) (high confidence), maritime trade (Box 8 CCP6.1), natural resource development (CCP6.2.4.1) (medium confidence), tourism (CCP6.2.4.2), and 9 transportation (including shipping) (CCP6.2.4.3; FAQ CCP6.2). Hundreds of billions of dollars are expected 10 to be invested in the polar regions in the next several decades (Lloyd's, 2012; Barnhart et al., 2016; 11 Pendakur, 2017; Tsukerman et al., 2019) and, as this unfolds, there are opportunities to simultaneously 12 implement adaptation strategies that support climate resilient development pathways in line with self- 13 determination for Indigenous Peoples and local communities and locally derived visions of successful 14 adaptation and development (CCP6.3.2, CCP6.4.3) (Jorgenson, 2007; Ritsema et al., 2015; Ready and 15 Power, 2017; Larsen and Petrov, 2020). | 3568 - 356 | Prot-Adapt-Mitig-Impac | | INDG |
| IPCC_AR6_WGII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Cross-Chapter Paper 6 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP6-22 Total pages: 66 1 2 3 CCP6.2.4.1 Changing access to natural resources with consequences for safety, economic development and 4 climate mitigation 5 6 Climate change is improving access to natural resources in the Arctic with consequences for human safety 7 (high confidence), economic development (very high confidence) and global mitigation efforts (medium 8 confidence). Reductions in sea-ice combined with improved extraction and transportation technologies have 9 increased accessibility to natural resources across the Arctic (Eliasson et al., 2017; Dawson et al., 2018b; 10 Stephen, 2018); a situation that could support continued global dependence on relatively cheap and abundant 11 fossil fuels resources and contribute to further warming. By 2040 (RCP4.5) it is expected that sea-ice will 12 have receded enough to make gas production technologically feasible in the European off-shore Arctic 13 (Petrick et al., 2017). However, increased sea-ice mobility, iceberg abundance, storm surge, and surface 14 wave action (Ng et al., 2018; Howell and Brady, 2019; Casas-Prat and Wang, 2020) will also increase risks 15 to ships servicing mines in a region that already exhibits disproportionately high accident rates (Council of 16 Canadian Academies, 2016) (CCP6.3.1, Table CCP6.1). Season lengths for ship-based support to mines and 17 extraction sites will increase with sea-ice change, while access via ice roads will decrease with warming 18 (Perrin et al., 2015; Council of Canadian Academies, 2016; Trofimenko et al., 2017; Southcott and Natcher, 19 2018). By 2050, climate change impacts to the Tibbitt to Contwoyto Winter Road servicing mines in the 20 northeastern region of the Northwest Territories, Canada could cost between $55 million to $213 million 21 CAD to maintain for a shorter period of time than at present (Perrin et al., 2015). Changes in submarine 22 permafrost, critical to mining infrastructure, such as pipelines and offshore infrastructure (Bashaw et al., 23 2016; Paulin and Caines, 2016), are expected to increase production costs and impact safety for workers 24 (Riedel et al., 2017). By mid-century, regardless of emissions scenario, it is expected that risks from 25 permafrost thaw will be disproportionately high for industrial infrastructure along major pipeline systems in 26 Alaska and natural gas extraction areas in the Yamal-Nenets region in northwestern Siberia, Russia (Hjort et 27 al., 2018). | 3568 - 356 | Prot-Adapt-Mitig-Impac | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 28 29 CCP6.2.4.2 Changing demand, opportunities and risks for polar tourism 30 31 Climate change has increased risks to, and demand for, polar tourism experiences related to increased 32 maritime accessibility (high confidence), lengthening of warm weather season lengths (very high confidence) 33 and development of a 'last chance tourism market' (medium confidence). Reductions in sea-ice extent have 34 facilitated increased access for polar cruising (Dawson et al., 2018b; Stewart et al., 2020). Demand for Arctic 35 cruises has increased by 20.5% over the past five years and resulted in 27.2 million passengers in 2018 36 (Shijin et al., 2020). In the Antarctic, tourist numbers increased by 27% from 1992-2018 and attracted 37 75,000 visitors in 2019-2020 (IAATO, 2020; Shijin et al., 2020), making it the largest economic sector in the 38 entire region (Stewart et al., 2020). The recent increase in polar tourism is due in part to the development of 39 a niche market called 'last chance tourism', which involves explicitly marketing vulnerable or vanishing 40 destinations or features (i.e., glaciers, polar bears, landscapes) and encouraging tourists to see them 'before 41 they are gone' (Dawson et al., 2018a; Groulx et al., 2019). However, tourism development opportunities will 42 also contend with ongoing risks related to the COVID19 pandemic, which halted tourism globally in 2020- 43 2021 (Frame and Hemmings, 2020; Lorenzo et al., 2020), as well as those related to increased climatic risks 44 limiting participation and reducing safety and security. By 2100 under RCP8.5, snow cover season length 45 suitable for winter recreational activities is projected to decrease by 21−49% in West Greenland (Schrot et 46 al., 2019). Reduced sea-ice and snow cover creates hazards for and could limit dog sledding, cross country 47 skiing, snowmobiling and floe edge tours, with limited adaptation strategies available for low elevation areas 48 (Stephen, 2018; Palma et al., 2019). | 3569 - 356 | 'rot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGII_Full_Report | 18 19 The polar seas have captured the imagination of global nations for centuries for its natural resource, 20 tourism, scientific, and maritime trade potential. As the polar regions are warming at two to three times the 21 rate of the global average leading to rapid reductions in sea-ice extent and thickness, international attention 22 has been reinvigorated and investments are being made by Arctic and non-Arctic nations alike with a view to 23 utilize newly accessible seaways. Between 2013 and 2019 ship traffic entering the Arctic grew by 25% and 24 the total distance travelled increased by 75%. Similar shipping growth trends are evident in the Antarctic 25 albeit to a lesser extent. Expected growth in Arctic shipping will influence a suite of cascading 26 environmental and cultural risks with implications for Indigenous Peoples. | 3570 - 357 | Impact | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 27 28 29 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Cross-Chapter Paper 6 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP6-24 Total pages: 66 1 Figure FAQ CCP6.2.1: Projected operational accessibility along Arctic maritime trade routes (Northwest Passage, 2 Transpolar Route, and Northern Sea Route) under future warming (left) and observed increases in commercial ship 3 traffic along the routes from 2012-2019 4 5 6 There has been debate among shipping stakeholders, rightsholders, and experts about the extent to which 7 climate change and sea-ice change is directly influencing increases in shipping activity in the polar regions 8 relative to other social, technological, political, and economic factors such as commodity prices, tourism 9 demand, global economic trends, infrastructure support, and service availability. Understanding the 10 connection between climate change and polar shipping activity will allow for more reliable projections of 11 possible future traffic trends and will aid in identifying appropriate adaptation and infrastructure needs 12 required to support future management of the industry. Recent studies have observed increasing statistical 13 correlations between sea-ice change and shipping trends in the polar regions and many have concluded that 14 although economic factors remain the main driver of shipping activities, followed by infrastructure 15 availability, climate change does indeed play a varying but important role in influencing operator intentions. | 3570 - 357 | Prot-Adapt-Mitig- | INTANBILE | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 49 50 There are three identified trade routes in the Arctic: Northern Sea Route (NSR), Northwest Passages (NWP), 51 and the Transpolar Sea Route (TSR). Over the last decade economic trends and reductions in sea-ice have 52 facilitated significant increases in ship traffic in the NSR (Aksenov et al., 2017; Li et al., 2020), including a 53 79% increase in total transit tonnage from 2010 to 2017 (Babin et al., 2020) related mostly to domestic 54 resource development. Relative to an early 21st century baseline, it is expected that the NSR will become 55 18% more accessible by mid-century (Stephenson et al., 2013) and could navigable even for non-ice 56 strengthened vessels for 101-118 days annually by 2050 and 125-192 days by 2100 (Khon et al., 2017). The 57 NWP has experienced a tripling of km travelled by ships since 1990, attributed mostly to resource extraction ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Cross-Chapter Paper 6 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP6-25 Total pages: 66 1 and increases in tourism opportunities (Johnston et al., 2017; Dawson et al., 2018a). The NWP could become 2 30% more accessible by 2050 compared to current conditions (Stephenson et al., 2013). Before 4°C global 3 warming above pre-industrial, re-supply vessels (Polar Class 7) in the western NWP could gain an additional 4 month of operating time, whereas the eastern NWP could gain just two weeks (Mudryk et al., 2021) due to 5 the dynamic import of mobile and hazardous ice from the Arctic Ocean (Haas and Howell, 2015; Howell and 6 Brady, 2019). Comparatively, the TSR has historically only been viable for nuclear icebreakers, submarines, 7 and occasional military and scientific activity due to thick multiyear ice regimes (Bennett et al., 2020). | 3571 - 3572 | | | |
| IPCC_AR6_WGII_Full_Report | 43 44 Climate change has important intangible loss and damage implications in the Arctic, with negative impacts 45 ranging from livelihoods to spirituality to solastalgia (i.e. distress caused by environmental change) (Cunsolo 46 and Ellis, 2018; Middleton et al., 2020b; Sawatzky et al., 2020; Mustonen and Shadrin, 2021). Permafrost 47 thaw, SLR, and reduced sea-ice protection also presents risk to socio-cultural assets, including heritage sites 48 in all Arctic regions (very high confidence) (Friesen, 2015; Hollesen et al., 2016; Radosavljevic et al., 2016; 49 O'Rourke, 2017; Hillerdal et al., 2019; Fenger-Nielsen et al., 2020; Jensen, 2020). A large number of 50 archaeological sites are at risk from climate change in southwest Greenland; Yukon's Beaufort coast, 51 Canada; and Auyuittuq National Park Reserve, Nunavut, Canada (Westley et al., 2011; Hollesen et al., 2018; 52 Irrgang et al., 2019; Fenger-Nielsen et al., 2020). Siberian nomadic reindeer herding and fishing livelihoods 53 are vulnerable to permafrost thaw, which alters northern landscapes and lakes, as well as rain-on-snow 54 events, and rapidly changes landscapes and terrestrial and aquatic habitats (Mustonen and Mustonen, 2016; 55 Brattland and Mustonen, 2018; Mustonen and Huusari, 2020) (CCP6.2.2). The intangible loss and damage to 56 nomadic cultures could cascade to losses of identity and social challenges (CCP6.2.6; Chapter 13). | 3573 - 357 | 'rot-Adapt-Mitig-Impac | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 51 52 Climate change has negative, widespread and cumulative impacts on mental health in the Arctic, particularly 53 for Indigenous Peoples (very high confidence) (Figure CCP6.3). Climate-sensitive mental health outcomes 54 are complex, overlapping, and interrelated, and have multiple direct and indirect pathways stemming from: 55 acute (e.g., major storms, flooding, wildfires) and chronic (e.g., temperature increases, sea-ice loss, 56 permafrost thaw) environmental conditions, and resulting disruptions to livelihoods, culture, food systems, 57 social connections, health systems, and economies (Cunsolo Willox et al., 2013a; Cunsolo Willox et al., ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Cross-Chapter Paper 6 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP6-28 Total pages: 66 1 2013b; Cunsolo Willox et al., 2014; Beaumier et al., 2015; Durkalec et al., 2015; Hamilton et al., 2016; 2 Clayton et al., 2017; Dodd et al., 2018; Jaakkola et al., 2018; Markon et al., 2018; ITK, 2019; Minor et al., 3 2019; Middleton et al., 2020a; Middleton et al., 2020b; Feodoroff, 2021). | 3574 - 357 | Impact | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 7 8 Indigenous knowledge systems are diverse among and within Arctic Indigenous Peoples, and reflect deep 9 and rich knowledge that situates and contextualizes values, traditions, governance, and practical ways of 10 adapting to the ecosystem over millennia (Raymond-Yakoubian et al., 2017; Brattland and Mustonen, 2018). | 3577 - 357 | Prot-Adapt-Mitig- | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 25 26 Climate change, nomadic lifestyles, and preservation of traditions 27 28 Perspectives from the Yukaghir Council of Elders and Russian Association of Indigenous Peoples, Russia 29 30 Climate change threatens reindeer herding, hunting, fishing, and gathering, which form the basis of Siberian 31 Indigenous societies. Nomadic herding lifestyle is premised on Indigenous knowledge which has 32 accumulated over millennia. IK, including the ability to predict weather, has played a substantial role in the 33 adaptation to the extreme conditions. According to Shadrin (2021) present, rapid changes are changing 34 Indigenous concepts of reality - they are increasingly finding themselves in situations where their experience 35 and knowledge cannot help them. An Elder in Northeast Siberia explained that "nature does not trust us 36 anymore" (Mustonen and Shadrin, 2021). | 3577 - 357 | Prot-Adapt-Mitig- | INTANBILE | INDG |

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|---|---|---|---|---|---|
| IPCC_AR6_WGII_Full_Report | 56 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Cross-Chapter Paper 6 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP6-31 Total pages: 66 1 Climate change impacts Indigenous Peoples' health. Degradation of the quality of surface waters has 2 increased, resulting from new floods and the thawing of permafrost, which increases risk of gastrointestinal 3 diseases (CCP6.2.8). The 2007 flood on Alazaya river was of special importance and was locally identified 4 to have produced the first regional "climate refugees" (Mustonen and Shadrin, 2021). Warming has 5 expanded the distribution of new disease-carrying insects and ticks into new territories (Mustonen and 6 Shadrin, 2021). Ancient cemeteries and campsites, as well as the burial sites of reindeer, become dangerous 7 as permafrost thaws and coastal erosion proceeds. | 3577 - 357 | Impact | | INDG |
| IPCC_AR6_WGII_Full_Report | 8 9 Traditional food security is under threat. Permafrost-based storage facilities have deteriorated (CCP6.2.6) 10 (Mustonen and Shadrin, 2021). There is an increase in the number of people who are forced to abandon the 11 consumption of raw fish. As a result, the likelihood of losing cultural traditions is growing. These combined 12 climate change impacts result in loss of Indigenous knowledge and nomadic lifestyles, thus, losing important 13 aspects of their identity as distinct Indigenous Peoples (Mustonen and Shadrin, 2021). | 3578 - 357 | Impact | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 42 43 The extraordinary developments in the field of Indigenous Knowledge have crystallized the main tenant of 44 interaction with the natural world that is "integral to a cultural complex that also encompasses language, 45 systems of classification, resource use practices, social interactions, ritual and spirituality" (UNESCO, 46 2017). Inuit have used their knowledge of the land and coastal seas to design technology, monitoring 47 systems (Atlas of Community-Based Monitoring in a Changing Arctic, 2021), and new hunting routes that 48 respond to the changes they face (Inuit Circumpolar Council, 2017; Nunavut Climate Change Center, 2018; 49 SIKU, 2020). Such examples of 'adaptation success' across Inuit Nunaat have been showcased and 50 celebrated nationally and internationally (Youth Climate Report, 2019) and all are underpinned by Inuit 51 knowledge and pivot on their right to self-determination. This is also embodied, for example, in Canada, the 52 National Inuit Climate Change Strategy outlines the collective Canadian Inuit plan for climate action, 53 centering on Inuit-determined priorities to protect their culture, language, and way of life, and guiding 54 partners in how to work with Inuit on implementing this strategy (ITK, 2019). Their action on adaptation 55 also spans scales from local to international. As far back as 1977, Inuit have been organized and involved at 56 the international level. Inuit were present at the Rio Earth Summit and have participated in diverse but 57 interrelated United Nations conventions to protect their homelands (e.g., UNFCCC, CBD, Stockholm ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Cross-Chapter Paper 6 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP6-32 Total pages: 66 1 Convention). This history gives us unique insight and positions us as both leaders and partners with the 2 ability to engage directly with governments, business, and others. | 3578 - 357 | Prot-Adapt-Mitig- | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 8 9 Central to their significant capacity to adapt is that it is done in recognition of the need to move beyond 10 adaptation. Indeed, Inuit-led adaptation action is founded on the intention of contributing to and moving 11 towards reformation and eventual transformation of systems to create a 'climate resilient' Arctic. This 12 concept has surfaced in academic climate change literature and discussion and has begun to filter into the 13 climate policy arena, especially within the context of the current COVID-19 pandemic that challenges us all 14 to think about our world differently. With acknowledgement that reform and transformation is needed, the 15 question remains, 'What does this look like?' 16 17 Inuit have an answer. System reform and transformation is grounded in self-determination. It is based in a 18 human rights framework and rooted in Indigenous knowledge and culture. It recognizes and respects 19 interconnectedness and builds this into solutions. It demands collaboration and true partnership towards 20 action. And it comes from thinking big and across scales. Shaping this change calls for willingness and 21 support to rethink the current economic and governance models that have failed us. For example, 22 decentralizing governance and management, while it remains largely unconventional, has been shown to 23 create some of the strongest systems we have. This is, in a large part, due to the way in which 24 decentralization places more value and responsibility on the 'self' in self-determination. Decentralized 25 processes in the Arctic have Indigenous knowledge holders playing a key and lead role in determining, 26 defining, deciding how to work towards positive change. | 3579 - 357 | Prot-Adapt-Mitig- | | INDG |

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| IPCC_AR6_WGII_Full_Report | Sector Direct and cascading risks Enabling principles of climate resilience pathways Anticipated future conditions / level of certainty Compounding risks (non-climatic factors) Coastal settlements (CCP6.2.5) Change in extent of sea�ice with more storm surges, thawing of permafrost, sea level rise, and coastal erosion Local leadership and community-led initiatives to initiate and drive processes, responsive agencies, established processes for assessments and planning, geographic options Increasing number of communities needing relocation (medium confidence), rising costs for mitigating erosion (high confidence) Limitations of government budgets, other disasters that may take priority, policies deficiencies for addressing mitigation and relocation Human health (CCP6.2.6) Increased food insecurity, waterborne disease, emerging pathogens, injury and death, and negative mental health outcomes Resources to support public programs; Indigenous self�determination; access to technology; supporting Indigenous knowledge systems; interdisciplinary and integrated decision�making The intersection of social determinants of health will modify or mediate climate change impacts on health (very high confidence) Underlying health conditions, advances in diagnosis and treatment, and other health system shocks (e.g., COVID) ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Cross-Chapter Paper 6 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP6-37 Total pages: 66 Transportation (aviation, rail, road, ice roads) (CCP6.2.4.3) Permafrost thaw, sea�ice change, storm surge, coastal erosion, changing precipitation patterns (ice pellets, hail), and extreme events create risks to transportation infrastructure with consequences to navigation, economics, safety, and security Financial and human resources for: climate resilient infrastructure research, development and implementation; improved weather, water, ice and climate forecasting at appropriate scales; improved communications infrastructure; local search and rescue Limits to adaptation exist (high confidence), but strategic investments in technologically innovative infrastructure that offers mitigation co-benefits will greatly enhance adaptation effectiveness (very high confidence) Level of local, regional, and national infrastructure development, commitment of national and state level government to sustainable development pathways, global economic and political trends, commodity prices, unforeseen system shocks Shipping (Box CCP6.1; FAQ CCP2) Sea-ice reduction leading to increased shipping related to trade, tourism, fisheries, resource development, and re-supply with cascading risks from ships such as: increased under-water noise, potential introduction of invasive species, fuel spill risks, release of black carbon and air emissions, impacts to cultural resources, implications for subsistence hunting and food security, increased accidents and incidents Financial support for ship-building technologies (e.g., low emission fuels, propulsion technologies, hull strength); development of robust multi-national agreements (in addition to existing agreements); inclusion of Indigenous Peoples in decision�making; investment in multi-national and longitudinal research on shipping impacts; and enhancing modern digital maritime charting Ship traffic will continue to grow in polar regions (high confidence) with Arctic trade routes becoming increasing accessible (very high confidence) albeit with more challenging navigation due to increases in mobile ice in the near�term compared to late century when ice is expected to diminish completely during the shipping season | 3583 - 358 | Prot-Adapt-Mitig-Impac | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | Declines in catch impact livelihoods, coastal communities, and pose a risk to regional and global food and nutritional security (very high confidence) Changes in global demand for seafood, demand and markets, changes in gear, changes in policies affecting property rights. Changes due to offshore development and transportation Marine subsistence (CCP6.2.3; CCP6.2.3.1) Changes in species distribution and abundance (not all negative); impediments to access of harvesting areas especially sea-ice; increased interactions with shipping; safety; changes in seasonality; reduced harvesting success and process of food production (processing, food storage; quality); threats to culture and food security Systems of adaptive co�management that allow for species switching, changes in harvesting methods and timing, secure harvesting rights, communication and relationship building, co-production of knowledge Changes in distribution and abundance of resources combined with more regulations related to species at risk. Adaptation at the local, individual, and household level under low mitigation scenarios will be costly and possibly undermined by the scale and pace of change, including climate shocks and extreme events (medium confidence) Changes in cost of fuel, land use affecting access, food preferences, harvesting rights; colonialism, international agreements to protect vulnerable species Marine ecosystems (CCP6.2.1) Warming, sea-ice loss, ocean acidification resulting in poleward contraction of polar zones, invasive species introduction, displacement of polar species, and restructuring of food webs Reduce effects of external and compounding risks and increase application of ecosystem-based management to meet biodiversity and management goals. | 3585 - 358 | Prot-Adapt-Mitig-Impac | | |

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| IPCC_AR6_WGII_Full_Report | Conservation of genetic diversity and biodiversity to preserve resilience, and Without institutional investment in sustaining climate resilience in ecosystems across sectors there is a high risk of failure (high confidence) Novel and expanding activities in ice free areas (shipping; fishing), energy development and mineral extraction, increased tourism, global markets and demand for polar resources, population growth and community ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Cross-Chapter Paper 6 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP6-39 Total pages: 66 supplementation and assisted migration may be needed relocation to coastal areas Terrestrial and Freshwater ecosystems (CCP6.2.2) Warming, hydrology changes (reduced ice on lakes and rivers, flooding, snow) and permafrost thaw lead to impacts on polar terrestrial and freshwater systems, food webs, the distribution of polar fish, implications for peat systems with consequent changes on dependent animal assemblages and increasingly favorable conditions for parasites and pathogens. | 3585 - 358 | 'rot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGII_Full_Report | Novel and expanding activities in ice free areas (shipping; fishing), energy development and mineral extraction, increased tourism, global markets and demand for polar resources, population growth and community relocation to coastal areas 1 2 3 4 5 Figure CCP6.6: Assessment of feasibility and effectiveness of adaptation options by key risks in the polar regions 6 (Table CCP6.6) 7 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Cross-Chapter Paper 6 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP6-40 Total pages: 66 1 2 The need for self-determination for Indigenous Peoples and local communities in decision-making and 3 cooperation across Arctic nations to manage a rapidly changing Arctic is increasingly recognized, 4 particularly in a shipping and wildlife management context where climate impacts will be transboundary and 5 multi-sectoral (Spence, 2017; Forbis and Hayhoe, 2018; Ford and Clark, 2019; Dawson et al., 2020) 6 (CCP6.2.6; Box CCP6.2). Effective Indigenous and community-led adaptation efforts have been 7 implemented across the Arctic to alleviate climate and non-climate stressors and build resilience through 8 restoration and conservation (Huntington et al., 2017; Brattland and Mustonen, 2018; Hudson and Vodden, 9 2020; Mustonen and Feodoroff, 2020; Uboni et al., 2020; Huntington et al., 2021). For example, Indigenous 10 knowledge and science has been used by the Skolt Sámi in Finland to attenuate warming, drought, and water 11 quality impacts on salmonids through restoration of spawning and nursery habitats in the Vainosjoki river 12 catchment (Brattland and Mustonen, 2018; Mustonen and Feodoroff, 2020; Ogar et al., 2020). This 13 ecological restoration of damaged habitats for fish represents community-led actions. In Aasiaat, 14 Greenlandic hunters have implemented community-based oceanographic and ecological monitoring to 15 convey Indigenous knowledge observations of rapid change to the government and scientists. A special 16 aspect of land use in the Russian North is the preservation of nomadic lifestyles of the Nenets and Chukchi 17 (Mustonen and Mustonen, 2016), and while these traditional economies have undergone rapid change due to 18 non-climate drivers, their land uses, observational frameworks and cultural matrixes remain of high 19 importance in the context of climate change. Endemic responses (self-agency from within the culture) and 20 Indigenous governance enable adaptation to the rapid and accelerating changes under way (Mustonen et al., 21 2018a). Therefore, community-based monitoring and inclusion of Indigenous knowledge in dialogue with 22 science has been an effective mechanism to detect and respond to climate change. | 3586 - 358 | 'rot-Adapt-Mitig-Impa | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 23 24 CCP6.3.2.2 Adaptation gaps 25 26 In a study of adaptation progress across the Arctic from 2004−2019, 233 cases of adaptation were 27 documented, with the majority of actions primarily behavioural and reactionary in nature and undertaken in 28 the subsistence harvesting sector, with resource management, and infrastructure and transportation other 29 prominent sectors where adaptation responses were documented to be occurring (Canosa et al., 2020). The 30 study found few changes in the profile of adaptation over time, except for an increase in responses being 31 motivated solely by climate impacts, and few cases of transformational change, although caution that a lack 32 of data on adaptation actions makes documenting trends challenging. Human health is generally under- 33 represented in adaptation initiatives, along with adaptations being developed within larger Arctic settlements 34 (Ford et al., 2014; Canosa et al., 2020), and in many sectors decisions continue to be made without explicit 35 inclusion of climate change impacts and risk in planning and design (high confidence) (Cherry et al., 2017; 36 Lauta et al., 2018; Meredith et al., 2019). There is limited evidence of transformational adaptation taking 37 place in the policy arena (e.g., U.S. Executive Order 13990, 2021), but many examples of how impacts and 38 responses to climate change have transformed social-ecological connections, traditions, markets, trade, and 39 livelihoods of Arctic residents and Indigenous Peoples (Ford et al., 2015). | 3587 - 358 | 'rot-Adapt-Mitig-Impa | INTANBILE | INDG |

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| IPCC_AR6_WGII_Full_Report | 13 14 There are significant limits to adaptation in the polar regions related to the rate of warming and cascading 15 changes that are occurring, which is equivalent to double and sometimes triple the global average depending 16 on the region (Bush and Lemmen, 2019; IPCC, 2021). The rapid pace of change, such as sea-ice loss, can 17 outpace ecological processes and induce substantial ecological shifts (CCP6.2)(medium confidence). The 18 speed of climate change in the Arctic limits options for adaptation in communities who rely on a narrow 19 resource base, when adaptation involves loss of culture and livelihoods, and when the costs of adaptation 20 makes it infeasible (medium confidence) (Ford et al., 2015), such as for reindeer herding (Table CCP6.6; 21 Figure CCP6.6; Figure CCP6.7) (Meredith et al., 2019). Adapting infrastructure in response to a rapidly 22 changing cryosphere will be limited by available technologies and the relatively higher costs associated with 23 updating infrastructure over vast polar regions (Schneider von Deimling et al., 2021). | 3588 - 358 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGII_Full_Report | 32 33 [END FAQ CCP6.4 HERE] 34 35 36 CCP6.4 Climate Resilient Development Pathways 37 38 The polar regions are expected to experience many economic development opportunities as a result of 39 climate change, including increased accessibility for shipping and attractiveness for fisheries and tourism 40 (CCP6.2.3.1, CCP6.2.4). For polar regions, equitable climate resilient development requires diverse 41 perspectives in planning and implementation. In the Arctic, cultural, social and economic dimensions of 42 Indigenous Peoples and local communities are critical (Ritsema et al., 2015; Huntington et al., 2021). For 43 both poles, there are global cultural connections to polar systems (Roberts et al., 2021), along with important 44 global and local needs for sustained ecosystems and their services, in the face of diminishing polar zonal 45 conditions (Cavanagh et al., 2021; Murphy et al., 2021; Solomonsz et al., 2021). | 3589 - 3589 | | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 14 15 Many losses and damages within Indigenous contexts are not able to be monetized but can be profound, such 16 as loss of Indigenous languages (CAFF, 2013), loss of Indigenous knowledge associated with nomadic 17 lifestyles and cultures (Box CCP6.2), and loss of geographical knowledge associated with an intimate 18 knowledge of landscapes across seasons (Brattland and Mustonen, 2018), changing landscapes resulting in 19 solastalgia and ecological grief (Cunsolo and Ellis, 2018), and some Indigenous practices and cultural assets, 20 such as burial grounds, nomadic camp sites, graveyards, seasonal dwellings, and routes and pathways 21 causing disruptions to mind and memory (Mustonen and Mustonen, 2016). Recognizing these intangible 22 losses and damages is critical for understanding how to achieve climate resilience in the Arctic (Tschakert et 23 al., 2019; Sawatzky et al., 2020). | 3590 - 359 | Impact | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 48 49 The net outcome of the population dynamics processes of growth, mortality and regeneration is change in 50 species composition as a consequence of a changing climate. In the Amazon forests, dry habitat-affiliated 51 genera have become more abundant among the newly recruited trees, while the mortality of moist habitat- 52 affiliated genera has increased at places where the dry season has intensified most, thus driving a slow shift 53 towards a drier forest type (Esquivel-Muelbert et al. 2019). A similar multi-decadal shift in West-African 54 forest species composition towards more dry-affiliated species as a response to long-term drying has been 55 recorded (Aguirre-Gutiérrez et al. 2020). While upward shifts in the tree line and in the range of individual 56 tree species have been recorded at several temperate mountain regions, evidence from the tropics is rare. A 57 large-scale study from 200 plot inventories of >2000 tree species across a ~3000m elevation gradient in the ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Cross-Chapter Paper 7 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP7-12 Total pages: 63 1 Andean tropics and sub-tropics has shown that the relative abundances of tree species from lower, warmer 2 locations were increasing at these sites indicating that “thermophilization of vegetation” (increased 3 domination of plant species from warmer locations) was indeed taking place as expected (Fadrique et al. | 3624 - 3625 | | | |
| IPCC_AR6_WGII_Full_Report | 5 6 For the Amazon, deforestation (ca. 40% of the region) in combination with climate change will raise the 7 prospect of passing a tipping point leading to large-scale savannization of the rainforest biome, but but uncertain remains that this will take place in the 21st 8 century (Nobre et al. 2016; Jia et al. 2019; Douville et 9 al. 2021). However, considering that the Amazon has already lost ca. 20% of its forests (Nobre et al. 2016), 10 crossing the tipping point may not only create savannas of the deforested parts but may also result in 11 precipitation reductions of 40% in non-deforested parts of the western Amazon due to a breakdown of the 12 South American monsoonal circulation and the subsequent western cascade of precipitation and 13 evapotranspiration (Boers et al. 2017). Other effects of forest degradation include loss of ecosystem services, 14 biodiversity, carbon storage, and indigenous culture (Watson et al. 2018; Strassburg et al. 2019; Gatti et al. | 3628 - 362 | Impact | | INDG |

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| IPCC_AR6_WGII_Full_Report | 30 31 32 [START BOX CCP7.1 HERE] 33 34 Box CCP7.1: Indigenous Knowledge and Local Knowledge and Community-Based Adaptation 35 36 Purely scientific knowledge, albeit indispensable, is insufficient to address climate change. Indigenous 37 Knowledge systems, embedded in social and cultural structures, are integral to climate resilience and 38 adaptation (high confidence) (Ajani 2013; Tengö et al. 2014; Hiwasaki et al. 2015; Roue and Nakashima 39 2018)[AR5 WG2 12.3.3, 14.3.1, 20.4.2 , SRCCL 4.8.1, 4.8.2, SR15 4.3.5]. Indigenous knowledge and local 40 knowledge (IK and LK) and community-based adaptation (CbA) have received increasing recognition across 41 all sectors (high confidence) (Reid and Huq 2014; Wright et al. 2014; MOSTE 2015)[SRCCL 4.1.6, 5.3.5, 42 SR15 Box 4.3] (Figure Box CCP7.1.1). Forest Indigenous knowledge is closely linked to traditional land-use 43 practices and local governance (Roberts et al. 2009); it is embodied in art, rituals, food, agriculture and 44 customary laws, among others (Hiwasaki et al. 2015; Camico et al. 2021). CbA is a community led process 45 based on its desires, priorities, knowledge and capacities; which empowers people as central players in 46 climate change adaptation (Reid et al. 2009) [SRCCL 5.3.5]. | 3629 - 362 | Prot-Adapt-Mitig- | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 52 53 Role of IK and LK and CbA for Climate Change Adaptation in Tropical Forests 54 55 Local forest and Indigenous forest management systems have developed over long time periods; generating 56 social practices and institutions that have supported livelihoods and cultures for generations (high 57 confidence) (Seppälä 2009; Martin et al. 2010; Parrotta and Agnoletti 2012; Camico et al. 2021). Archaeological evidence shows that humans have manipulated tropical forests for at least 1 45 thousand years 2 (high confidence). Indigenous Peoples usually consider themselves as parts of socio-ecosystems, protecting 3 the forest by maintaining healthy socio-ecological relationships and successfully adapting to environmental 4 change (Speranza et al. 2010; Swiderska et al. 2011; Parrotta and Agnoletti 2012; Uprety et al. 2012; Mistry 5 et al. 2016; Roberts et al. 2017) [AR5 WG2 12.3.2]. | 3629 - 362 | Prot-Adapt-Mitig- | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | 12 13 Integration of IK and LK Systems, CbA and Modern Scientific Systems 14 15 Several authors have highlighted the need to foster a respectful a dialogue between IK and LK and modern 16 science towards a holistic research model (high confidence) (Berkes 2010; Ajani 2013; Tengö et al. 2014; 17 Roue and Nakashima 2018)[AR5 WG2 12.3.3, 14.2.2]; but few ecological studies have attempted this 18 integration (Keenan 2015; Vadigi 2016). Examples in tropical forest ecosystems include topics such as 19 monitoring climate impacts; local climates; seed, water and land management resilience-increasing practices 20 and climate threats to traditional agriculture (Parrotta and Agnoletti 2012; Fernández-Llamazares et al. 2017; 21 Camico et al. 2021; Panduro Meléndez et al. 2021). A growing number of methods are available to help this 22 dialogue [SRCCL 7.5.1] (Reid et al. 2009; Tengö et al. 2014; Tengö et al. 2017; Roue and Nakashima 23 2018)(Figure Box CCP7.1.1). While there is expanding interest among decision-makers, researchers, 24 Indigenous Peoples and civil society on IK and LK (Hiwasaki et al. 2015; Maillet and Ford 2016), gaps 25 remain regarding links between place-and-culture dimensions and adaptive capacities (Ford et al. 2016). | 3630 - 363 | 'rot-Adapt-Mitig-Impac | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | (Lee 2017) 5 Gender Equality Within genders, other characteristics such as class, race, caste, culture, wealth, age and ethnicity influence responses and affect the impact of climate variability and change on livelihoods Despite challenges, Nepal's community forestry policy is considered one of the most progressive, as it allows women to exercise equal rights with men in the management and utilization of community forests. Furthermore, women-only forestry groups have registered many success stories. | 3644 - 364 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 25 The forests provide many kinds of economic products, such as timber, medicines, and food, recreational 26 services, such as nature trekking, bird and wildlife watching, to mention a few. Indigenous People and other 27 forest-dependent communities have shown extraordinary knowledge on how to manage forest resources to 28 meet their subsistence needs without causing forest degradation. This forest culture and wisdom are broken 29 when the rate of forest extraction changes into unplanned and unsustainable large-scale transformation. | 3652 - 3652 | | | INDG |
| IPCC_AR6_WGII_Full_Report | 30 31 Deforestation and land-use changes in tropical forests cause not only physical and biological changes on flora 32 and fauna but also rapid changes in cultures harming forest peoples. A degraded tropical forest is prone and 33 more vulnerable to climate change. An increase in temperature in lowlands creates an unfavorable condition 34 for optimum growths of many kinds of plant species, which affects, as well, several agricultural plants. Coffee 35 farmers, for example, are forced to open new forest frontiers in highland areas to meet an optimum temperature 36 for the growth of coffee. | 3652 - 3652 | | | |

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| IPCC_AR6_WGII_Full_Report | 10 11 To protect tropical forests a collective action of all nations is needed. It requires a global effort to stop 12 deforestation and the conversion of tropical forests. The role of Indigenous Peoples and local communities as 13 forest keepers must be strengthened. Economic incentives for protecting tropical forests, among other 14 strategies, could facilitate collective actions towards a sustainable management of tropical forests. Sustainable, 15 effective and just strategies to increase the resilience of tropical forests need to consider the complex political, 16 social and economic dynamics involved, including the goals, identity and livelihood priorities of Indigenous 17 Peoples and local communities beyond natural resource management. Strategies can benefit from integrating 18 knowledge and know-how from traditional cultures, fostering transitions towards more sustainable systems. | 3653 - 365 | ’rot-Adapt-Mitig-Impac | INTANBILE | INDG |
| IPCC_AR6_WGIII_Full_Report | The combined global discounted value of the unburned fossil fuels and stranded fossil fuel infrastructure APPROVED Summary for Policymakers IPCC AR6 WG III Subject to copyedit SPM-37 Total pages: 63 has been projected to be around 1–4 trillion dollars from 2015 to 2050 to limit global warming to approximately 2ºC, and it will be higher if global warming is limited to approximately 1.5ºC (medium confidence). In this context, coal assets are projected to be at risk of being stranded before 2030, while oil and gas assets are projected to be more at risk of being stranded toward mid-century. A low-emission energy sector transition is projected to reduce international trade in fossil fuels. (high confidence) {6.7, Figure 6.35} C.4.5 Global methane emissions from energy supply, primarily fugitive emissions from production and transport of fossil fuels, accounted for about 18% [13%-23%] of global GHG emissions from energy supply, 32% [22%-42%] of global methane emissions, and 6% [4%-8%] of global GHG emissions in 2019 (high confidence). About 50–80% of CH4 emissions from these fossil fuels could be avoided with currently available technologies at less than USD50 tCO2-eq-1 (medium confidence). {6.3, 6.4.2, Box 6.5, 11.3, 2.2.2, Table 2.1, Figure 2.5; Annex1 Glossary} C.4.6 CCS is an option to reduce emissions from large-scale fossil-based energy and industry sources, provided geological storage is available. When CO2 is captured directly from the atmosphere (DACCS), or from biomass (BECCS), CCS provides the storage component of these CDR methods. CO2 capture and subsurface injection is a mature technology for gas processing and enhanced oil recovery. In contrast to the oil and gas sector, CCS is less mature in the power sector, as well as in cement and chemicals production, where it is a critical mitigation option. The technical geological CO2 storage capacity is estimated to be on the order of 1000 gigatonnes of CO2, which is more than the CO2 storage requirements through 2100 to limit global warming to 1.5°C, although the regional availability of geological storage could be a limiting factor. If the geological storage site is appropriately selected and managed, it is estimated that the CO2 can be permanently isolated from the atmosphere. Implementation of CCS currently faces technological, economic, institutional, ecological-environmental and socio�cultural barriers. Currently, global rates of CCS deployment are far below those in modelled pathways limiting global warming to 1.5°C or 2°C. Enabling conditions such as policy instruments, greater public support and technological innovation could reduce these barriers. (high confidence) {2.5, 6.3, 6.4, 6.7, 11.3, 11.4, Cross-Chapter Box 8 in Chapter 12, Figure TS.31, SRCCS Chapter 5} APPROVED Summary for Policymakers IPCC AR6 WG III Subject to copyedit SPM-38 Total pages: 63 C.5 Net-zero CO2 emissions from the industrial sector are challenging but possible. Reducing industry emissions will entail coordinated action throughout value chains to promote all mitigation options, including demand management, energy and materials efficiency, circular material flows, as well as abatement technologies and transformational changes in production processes. Progressing towards net zero GHG emissions from industry will be enabled by the adoption of new production processes using low and zero GHG electricity, hydrogen, fuels, and carbon management. (high confidence) {11.2, 11.3, 11.4, Box TS.4} C.5.1 The use of steel, cement, plastics, and other materials is increasing globally, and in most regions. There are many sustainable options for demand management, materials efficiency, and circular material flows that can contribute to reduced emissions, but how these can be applied will vary across regions and different materials. These options have a potential for being more used in industrial practice | 37 - 39 | ’rot-Adapt-Mitig-Impac | | |

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| IPCC_AR6_WGIII_Full_Report | C.9.2 AFOLU carbon sequestration and GHG emission reduction options have both co-benefits and risks in terms of biodiversity and ecosystem conservation, food and water security, wood supply, livelihoods and land tenure and land-use rights of Indigenous Peoples, local communities and small land owners. Many options have co-benefits but those that compete for land and land-based resources can pose risks. The scale of benefit or risk largely depends on the type of activity undertaken, deployment strategy (e.g., scale, method), and context (e.g., soil, biome, climate, food system, land ownership) that vary geographically and over time. Risks can be avoided when AFOLU mitigation is pursued in response to the needs and perspectives of multiple stakeholders to achieve outcomes that maximize co-benefits while limiting trade-offs. (high confidence) {7.4, 7.6, 12.3} APPROVED Summary for Policymakers IPCC AR6 WG III Subject to copyedit SPM-44 Total pages: 63 C.9.3 Realising the AFOLU potential entails overcoming institutional, economic and policy constraints and managing potential trade-offs (high confidence). Land-use decisions are often spread across a wide range of landowners; demand-side measures depend on billions of consumers in diverse contexts. Barriers to the implementation of AFOLU mitigation include insufficient institutional and financial support, uncertainty over long-term additionality and trade-offs, weak governance, insecure land ownership, the low incomes and the lack of access to alternative sources of income, and the risk of reversal. Limited access to technology, data, and know-how is a barrier to implementation. Research and development are key for all measures. For example, measures for the mitigation of agricultural CH4 and N2O emissions with emerging technologies show promising results. However the mitigation of agricultural CH4 and N2O emissions is still constrained by cost, the diversity and complexity of agricultural systems, and by increasing demands to raise agricultural yields, and increasing demand for livestock products. (high confidence) {7.4, 7.6} C.9.4 Net costs of delivering 5-6 Gt CO2 yr-1 of forest related carbon sequestration and emission reduction as assessed with sectoral models are estimated to reach to ~USD400 billion yr-1 by 2050. The costs of other AFOLU mitigation measures are highly context specific. Financing needs in AFOLU, and in particular in forestry, include both the direct effects of any changes in activities as well as the opportunity costs associated with land use change. Enhanced monitoring, reporting and verification capacity and the rule of law are crucial for land-based mitigation, in combination with policies also recognising interactions with wider ecosystem services, could enable engagement by a wider array of actors, including private businesses, NGOs, and Indigenous Peoples and local communities. (medium confidence) {7.6, 7.7} C.9.5 Context specific policies and measures have been effective in demonstrating the delivery of AFOLU carbon sequestration and GHG emission reduction options but the above-mentioned constraints hinder large scale implementation (medium confidence). Deploying land-based mitigation can draw on lessons from experience with regulations, policies, economic incentives, payments (e.g., for biofuels, control of nutrient pollution, water regulations, conservation and forest carbon, ecosystem services, and rural livelihoods), and from diverse forms of knowledge such as Indigenous knowledge, local knowledge and scientific knowledge. Indigenous Peoples, private forest owners, local farmers and communities manage a significant share of global forests and agricultural land and play a central role in land-based mitigation options. Scaling successful policies and measures relies on governance that | 44 - 46 | Prot-Adapt-Mitig-Impac | | INDG |
| IPCC_AR6_WGIII_Full_Report | FOOTNOTE 64: Status consumption refers to the consumption of goods and services which publicly demonstrates social prestige. APPROVED Summary for Policymakers IPCC AR6 WG III Subject to copyedit SPM-46 Total pages: 63 Figure SPM.6 Indicative potential of demand-side mitigation options by 2050 Figure SPM.6 covers the indicative potential of demand-side options for the year 2050. Figure SPM.7 covers cost and potentials for the year 2030. Demand-side mitigation response options are categorised into three broad domains: 'socio-cultural factors', associated with individual choices, behaviour; and lifestyle changes, social norms and culture; 'infrastructure use', related to the design and use of supporting hard and soft infrastructure that enables changes in individual choices and behaviour; and 'end-use technology adoption', refers to the uptake of technologies by end-users. Demand side mitigation is a central element of the IMP-LD and IMP-SP scenarios (Figure SPM.5). | 46 - 47 | Prot-Adapt-Mitig- | INTANBILE | |

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| IPCC_AR6_WGIII_Full_Report | Upscaling the deployment of CDR depends on developing effective approaches to address feasibility and sustainability constraints especially at large scales. (high confidence) {3.4, 7.4, 12.3, Cross-Chapter Box 8 in Chapter 12} C.11.1 CDR refers to anthropogenic activities that remove CO2 from the atmosphere and store it durably in geological, terrestrial, or ocean reservoirs, or in products. CDR methods vary in terms of their maturity, removal process, timescale of carbon storage, storage medium, mitigation potential, cost, co-benefits, impacts and risks, and governance requirements (high confidence). Specifically, maturity ranges from lower maturity (e.g., ocean alkalinisation) to higher maturity (e.g., reforestation); removal and storage potential ranges from lower potential (<1 Gt CO2 yr -1 , e.g., blue carbon management) to higher potential (>3 Gt CO2 yr-1 , e.g., agroforestry); costs range from lower cost (e.g., 45-100 USD/tCO2 for soil carbon sequestration) to higher cost (e.g., 100-300 USD/tCO2 for DACCS) (medium confidence). Estimated storage timescales vary from decades to centuries for methods that store carbon in vegetation and through soil carbon management, to ten thousand years or more for methods that store carbon in geological formations (high confidence). The processes by which CO2 is removed from the atmosphere are categorised as biological, geochemical or chemical. Afforestation, reforestation, improved forest management, agroforestry and soil carbon sequestration are currently the only widely practiced CDR methods (high confidence). {7.4, 7.6, 12.3, Table 12.6, Table TS.7, Cross-Chapter Box 8 in Chapter 12, WG I 5.6} C.11.2 The impacts, risks and co-benefits of CDR deployment for ecosystems, biodiversity and people will be highly variable depending on the method, site-specific context, implementation and scale (high confidence). Reforestation, improved forest management, soil carbon sequestration, peatland restoration and blue carbon management are examples of methods that can enhance biodiversity and ecosystem functions, employment and local livelihoods, depending on context (high confidence). In contrast, afforestation or production of biomass crops for BECCS or biochar, when poorly implemented, can have adverse socio-economic and environmental impacts, including on biodiversity, food and water security, local livelihoods and on the rights of Indigenous Peoples, especially if implemented at large scales and where land tenure is insecure (high confidence). Ocean fertilisation, if implemented, could<br>APPROVED Summary for Policymakers IPCC AR6 WG III Subject to copyedit SPM-48 Total pages: 63 lead to nutrient redistribution, restructuring of ecosystems, enhanced oxygen consumption and acidification in deeper waters (medium confidence). {7.4, 7.6, 12.3, 12.5} C.11.3 The removal and storage of CO2 through vegetation and soil management can be reversed by human or natural disturbances; it is also prone to climate change impacts. In comparison, CO2 stored in geological and ocean reservoirs (via BECCS, DACCS, ocean alkalinisation) and as carbon in biochar is less prone to reversal. (high confidence) {6.4, 7.4, 12.3} C11.4 In addition to deep, rapid, and sustained emission reductions CDR can fulfil three different complementary roles globally or at country level: lowering net CO2 or net GHG emissions in the near�term; counterbalancing 'hard-to-abate' residual emissions (e.g., emissions from agriculture, aviation, shipping, industrial processes) in order to help reach net zero CO2 or net zero GHG emissions in the mid-term; achieving net negative CO2 or GHG emissions in the long-term if deployed at levels exceeding annual residual emissions (high confidence) {3.3, 7.4, 11.3, 12.3, Cross-Chapter Box 8 in Chapter 12} C.11.5 Rapid emission | 48 - 49 | Prot-Adapt-Mitig-Impact | | INDG |
| IPCC_AR6_WGIII_Full_Report | E.1.1 Several mitigation options, notably solar energy, wind energy, electrification of urban systems, urban green infrastructure, energy efficiency, demand side management, improved forest- and crop/grassland management, and reduced food waste and loss, are technically viable, are becoming increasingly cost effective, and are generally supported by the public. This enables deployment in many regions. (high confidence) While many mitigation options have environmental co-benefits, including improved air quality and reducing toxic waste, many also have adverse environmental impacts, such as reduced biodiversity, when applied at very large scale, for example very large scale bioenergy or large scale use of battery storage, that would have to be managed (medium confidence). Almost all mitigation options face institutional barriers that need to be addressed to enable their application at scale (medium confidence). {6.4, Figure 6.19, 7.4, 8.5, Figure 8.19, 9.9, Figure 9.20, 10.8, Figure 10.23, 12.3, Figure 12.4, Figure TS.31} E.1.2 The feasibility of mitigation options varies according to context and time. For example, the institutional capacity to support deployment varies across countries; the feasibility of options that involve large-scale land use changes varies across regions; spatial planning has a higher potential at early stages of urban development; the potential of geothermal is site specific; and capacities, cultural and local conditions can either inhibit or enable demand-side responses. The deployment of solar and wind energy has been assessed to become increasingly feasible over time. The feasibility of some options can increase when combined or integrated, such as using land for both agriculture and<br>APPROVED Summary for Policymakers IPCC AR6 WG III Subject to copyedit SPM-58 Total pages: 63 centralised solar production. (high confidence) {6.4, 6.6, 7.4, 8.5, 9.9, 10.8, 12.3, Appendix 10.3, Table SM6, Table SM8.2, Table SM9.1, Table SM12.B} E.1.3 Feasibility depends on the scale and speed of implementation. Most options face barriers when they are implemented rapidly at a large scale, but the scale at which barriers manifest themselves varies. | 58 - 59 | Prot-Adapt-Mitig-Impact | INTANBILE | |

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| --- | --- | --- | --- | --- | --- |
| IPCC_AR6_WGIII_Full_Report | 6 The ease of switching to electricity means that hydrogen is not expected to be a dominant pathway for 7 buildings {Box 9.6}. Using electricity directly for heating, cooling and other building energy demand 8 is more efficient than using hydrogen as a fuel, for example, in boilers or fuel cells. In addition, 9 electricity distribution is already well developed in many regions compared to essentially non-existent 10 hydrogen infrastructure, except for a few chemicals industry pipelines. At the same time, hydrogen 11 could potentially be used for on-site storage should technology advance sufficiently. | 120 - 120 | | | |
| IPCC_AR6_WGIII_Full_Report | 25 The scenarios literature projects continued growth in demand for freight and passenger services, 26 particularly in developing countries in Africa and Asia (high confidence). This growth is projected to 27 take place across all transport modes. Increases in demand notwithstanding, scenarios that limit 28 warming to 1.5°C degree with no or limited overshoot suggest that a 59% reduction (42-68% 29 interquartile range) in transport-related CO2 emissions by 2050, compared to modelled 2020 levels is 30 required. While many global scenarios place greater reliance on emissions reduction in sectors other 31 than transport, a quarter of the 1.5°C scenarios describe transport-related CO2 emissions reductions in 32 excess of 68% (relative to modelled 2020 levels) (medium confidence). Illustrative Mitigation Pathways 33 IMP-ren and IMP-LD (TS 4.2) describe emission reductions of 80% and 90% in the transport sector, 34 respectively, by 2050. Transport-related emission reductions, however, may not happen uniformly 35 across regions. For example, transport emissions from the Developed Countries, and Eastern Europe 36 and West-Central Asia countries decrease from 2020 levels by 2050 across all scenarios limiting global 37 warming to 1.5°C by 2100, but could increase in Africa, Asia and developing Pacific (APC), Latin 38 America and Caribbean, and the Middle East in some of these scenarios. {10.7} 39 The scenarios literature indicates that fuel and technology shifts are crucial in reducing carbon 40 emissions to meet temperature goals (high confidence). In general terms, electrification tends to play 41 the key role in land-based transport, but biofuels and hydrogen (and derivatives) could play a role in 42 decarbonisation of freight in some contexts. Biofuels and hydrogen (and derivatives) are expected to be 43 more prominent in shipping and aviation. The shifts towards these alternative fuels must occur 44 alongside shifts towards clean technologies in other sectors. {10.7} 45 There is a growing awareness of the need to plan for the significant expansion of low-carbon 46 energy infrastructure, including low-carbon power generation and hydrogen production, to 47 support emissions reductions in the transport sector (high confidence). Integrated energy planning ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Technical Summary IPCC AR6 WG III Do Not Cite, Quote or Distribute TS-69 Total pages: 142 1 and operations that take into account energy demand and system constraints across all sectors (transport, 2 buildings, and industry) offer the opportunity to leverage sectoral synergies and avoid inefficient 3 allocation of energy resources. Integrated planning of transport and power infrastructure would be 4 particularly useful in developing countries where 'greenfield' development doesn't suffer from 5 constraints imposed by legacy systems. {10.3, 10.4, 10.8} 6 The deployment of low-carbon aviation and shipping fuels that support decarbonisation of the 7 transport sector could require changes to national and international governance structures 8 (medium confidence). The UNFCCC does not specifically cover emissions from international shipping 9 and aviation. Reporting emissions from international transport is at the discretion of each country. While 10 the International Civil Aviation Organisation (ICAO) and International Maritime Organisation (IMO) 11 have established emissions reductions targets, only strategies to improve fuel efficiency and demand 12 reductions have been pursued, and there has been minimal commitment to new technologies. {10.5, 13 10.6, 10.7} 14 There are growing concerns about resource availability, labour rights, non-climate 15 environmental impacts, and costs of critical minerals needed for lithium-ion batteries (medium 16 confidence). Emerging national strategies on critical minerals | 132 - 135 | 'rot-Adapt-Mitig-Impac | | |

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| IPCC_AR6_WGIII_Full_Report | No data. {12.3.1} 1 Range based on authors' estimates (as assessed from literature) are shown, with full literature ranges shown in brackets ACCEPTED VERSION SUBJECT TO FINAL EDITS Final Government Distribution Technical Summary IPCC AR6 WG III Do Not Cite, Quote or Distribute TS-98 Total pages: 142 1 TS. 5.8 Demand-side aspects of mitigation 2 The assessment of the social science literature and regional case studies reveals how social norms, 3 culture, and individual choices interact with infrastructure and other structural changes over time. This 4 provides new insight into climate change mitigation strategies, and how economic and social activity 5 might be organised across sectors to support emission reductions. To enhance well-being, people 6 demand services and not primary energy and physical resources per se. Focusing on demand for services 7 and the different social and political roles people play broadens the participation in climate action. (Box 8 TS.11) 9 Demand-side mitigation and new ways of providing services can help Avoid and Shift final service 10 demands and Improve service delivery. Rapid and deep changes in demand make it easier for 11 every sector to reduce GHG emissions in the short and medium term (high confidence). {5.2, 5.3} 12 The indicative potential of demand-side strategies across all sectors to reduce emissions is 40-70% 13 by 2050 (high confidence). Technical mitigation potentials compared to the International Energy 14 Agency's 2020 World Energy Outlook STEPS (Stated Policy Scenarios) baseline are up to 5.7 GtCO2-eq for 15 building use and construction, 8 GtCO2-eq for food demand, 6.5 GtCO2-eq for land transport, and 5.2 16 GtCO2-eq for industry. Mitigation strategies can be classified as Avoid-Shift-Improve (ASI) options, 17 that reflect opportunities for socio-cultural, infrastructural, and technological change. The greatest 18 Avoid potential comes from reducing long-haul aviation and providing short-distance low-carbon urban 19 infrastructures. The greatest Shift potential would come from switching to plant-based diets. The 20 greatest Improve potential comes from within the building sector, and in particular increased use of 21 energy efficient end-use technologies and passive housing. (Figure TS.20, Figure TS.21) {5.3.1, 5.3.2, 22 Figure 5.7, Figure 5.8, Table 5.1, Table SM 5.2} 23 Socio-cultural and lifestyle changes can accelerate climate change mitigation (medium 24 confidence). Among 60 identified actions that could change individual consumption, individual 25 mobility choices have the largest potential to reduce carbon footprints. Prioritising car-free mobility by walking and cycling and adoption of electric mobility could save 2 tCO2-eq cap-1 yr-1 26 . Other options 27 with high mitigation potential include reducing air travel, cooling setpoint adjustments, reduced 28 appliance use, shifts to public transit, and shifting consumption towards plant-based diets. {5.3.1, 29 5.3.1.2, Figure 5.8} 30 31 START BOX TS.11 HERE 32 Box TS.11: A New Chapter in WG III AR6 Focusing on the Social Science of Demand, and 33 Social Aspects of Mitigation 34 The WG III contribution to the Sixth Assessment Report of the IPCC (AR6) features a distinct chapter 35 on demand, services and social aspects of mitigation {5}. The scope, theories, and evidence for such an 36 assessment are addressed in Sections 5.1 and 5.4 within Chapter 5 and a Social Science Primer as an 37 Appendix to Chapter 5. | 161 - 162 | Prot-Adapt-Mitig- | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | 6 A social science perspective is important in two ways. By adding new actors and perspectives, it (i) 7 provides more options for climate mitigation; and (ii) helps to identify and address important social and 8 cultural barriers and opportunities to socioeconomic, technological, and institutional change. Demand- 9 side mitigation involves five sets of social actors: individuals (e.g., consumption choices, habits), 10 groups and collectives (e.g., social movements, values), corporate actors (e.g., investments, 11 advertising), institutions (e.g., political agency, regulations), and infrastructure actors (e.g., very long- 12 term investments and financing). Actors either contribute to the status-quo of a global high-carbon, 13 consumption, and GDP growth-oriented economy, or help generate the desired change to a low-carbon 14 energy-services, well-being, and equity-oriented economy. Each set of actors has novel implications for 15 the design and implementation of both demand- and supply-side mitigation policies. They show 16 important synergies, making energy demand mitigation a dynamic problem where the packaging and/or 17 sequencing of different policies play a role in their effectiveness {5.5, 5.6}. Incremental interventions 18 change social practices, simultaneously affecting emissions and well-being. The transformative change 19 requires coordinated action across all five sets of actors (Table 5.4), using social science insights about 20 intersection of behaviour, culture, institutional and infrastructural changes for policy design and 21 implementation. Avoid, Shift, and Improve choices by individuals, households and communities support 22 mitigation {5.3.1.1, Table 5.1}. They are instigated by role models, changing social norms driven by 23 policies and social movements. They also require appropriate infrastructures designed by urban 24 planners and building and transport professionals, corresponding investments, and a political culture 25 supportive of demand side mitigation action. | 163 - 163 | Prot-Adapt-Mitig-Impac | INTANBILE | |

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| IPCC_AR6_WGIII_Full_Report | 26 END BOX TS.11 HERE 27 28 Leveraging improvements in end-use service delivery through behavioural and technological 29 innovations, and innovations in market organisation, leads to large reductions in upstream 30 resource use (high confidence). Analysis of indicative potentials range from a factor 10- to 20-fold 31 improvement in the case of available energy (exergy) analysis, with the highest improvement potentials 32 at the end-user and service-provisioning levels. Realisable service level efficiency improvements could 33 reduce upstream energy demand by 45% in 2050. (Figure TS.20) {5.3.2, Figure 5.10} ACCEPTED VERSION SUBJECT TO FINAL EDITS Final Government Distribution Technical Summary IPCC AR6 WG III Do Not Cite, Quote or Distribute TS-100 Total pages: 142 1 2 Figure TS.20: Demand-side strategies for mitigation. Demand-side mitigation is about more than 3 behavioural change and transformation happens through societal, technological and institutional changes 4 {Figure 5.10, Figure 5.14} 5 6 ACCEPTED VERSION SUBJECT TO FINAL EDITS Final Government Distribution Technical Summary IPCC AR6 WG III Do Not Cite, Quote or Distribute TS-101 Total pages: 142 1 2 Figure TS.21: Demand-side mitigation can be achieved through changes in socio-cultural factors, 3 infrastructure design and use, and technology adoption 4 Figure TS.21 legend: Mitigation response options related to demand for services have been categorised into 5 three domains: 'socio-cultural factors', related to social norms, culture, and individual choices and behaviour; 6 'infrastructure use', related to the provision and use of supporting infrastructure that enables individual choices 7 and behaviour; and 'technology adoption', which refers to the uptake of technologies by end users. | 163 - 165 | Prot-Adapt-Mitig- | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | 10 There are knowledge gaps for assessing CE opportunities within mitigation models due to CE's many 11 cross-sectoral linkages and data gaps related to its nascent state {3.4.4}. Opportunity exists to bridge 12 knowledge from the Industrial Ecology field, which has historically studied CE, to the mitigation 13 modelling community for improved analysis of interventions and policies for AR7. For instance, a 14 global CE knowledge sharing platform is helpful for CE performance measurement, reporting and 15 accounting. {5.3, 9.5, 11.7} 16 END BOX TS.12 HERE 17 18 Providing better services with less energy and resource input has high technical potential and is 19 consistent with providing well-being for all (medium confidence). The assessment of 19 demand- 20 side mitigation options and 18 different constituents of well-being showed that positive impacts on well- 21 being outweigh negative ones by a factor of 11. {5.2, 5.2.3, Figure 5.6} 22 Demand-side mitigation options bring multiple interacting benefits (high confidence). Energy 23 services to meet human needs for nutrition, shelter, health, etc. are met in many different ways with 24 different emissions implications that depend on local contexts, cultures, geography, available 25 technologies, and social preferences. In the near term, many less-developed countries, and poor people 26 everywhere, require better access to safe and low-emissions energy sources to ensure decent living 27 standards and increase energy savings from service improvements by about 20-25%. (Figure TS.22) 28 {5.2, 5.4.5, Figure 5.3, Figure 5.4, Figure 5.5, Figure 5.6, Box 5.2, Box 5.3} 29 Granular technologies and decentralized energy end-use, characterised by modularity, small unit 30 sizes and small unit costs, diffuse faster into markets and are associated with faster technological 31 learning benefits, greater efficiency, more opportunities to escape technological lock-in, and 32 greater employment (high confidence). Examples include solar PV systems, batteries, and thermal 33 heat pumps. {5.3, 5.5, 5.5.3} 34 Wealthy individuals contribute disproportionately to higher emissions and have a high potential 35 for emissions reductions while maintaining decent living standards and well-being (high 36 confidence). Individuals with high socio-economic status are capable of reducing their GHG emissions 37 by becoming role models of low-carbon lifestyles, investing in low-carbon businesses, and advocating 38 for stringent climate policies. {5.4.1, 5.4.3, 5.4.4, Figure 5.14} 39 Demand-side solutions require both motivation and capacity for change (high confidence). | 167 - 167 | Prot-Adapt-Mitig-Impac | INTANBILE | |

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| IPCC_AR6_WGIII_Full_Report | 31 International cooperation is emerging but so far fails to fully address transboundary issues associated 32 with solar radiation modification and carbon dioxide removal. {14.2, 14.3, 14.4, 14.5, 14.6, Cross- 33 Working Group Box 4 in Chapter 14} 34 35 TS. 6.3 Societal aspects of mitigation 36 Social equity reinforces capacity and motivation for mitigating climate change (medium 37 confidence). Impartial governance such as fair treatment by law-and-order institutions, fair treatment 38 by gender, and income equity, increases social trust, thus enabling demand-side climate policies. High 39 status (often high carbon) item consumption may be reduced by taxing absolute wealth without 40 compromising well-being. {5.2, 5.4.2, 5.6} 41 42 Policies that increase the political access and participation of women, racialised, and marginalised 43 groups, increase the democratic impetus for climate action (high confidence). Including more 44 differently situated knowledge and diverse perspectives makes climate mitigation policies more 45 effective. {5.2, 5.6} 46 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Technical Summary IPCC AR6 WG III Do Not Cite, Quote or Distribute TS-121 Total pages: 142 1 Greater contextualisation and granularity in policy approaches better addresses the challenges 2 of rapid transitions towards zero-carbon systems (high confidence). Larger systems take more time 3 to evolve, grow, and change compared to smaller ones. Creating and scaling up entirely new systems 4 takes longer than replacing existing technologies and practices. Late adopters tend to adopt faster than 5 early pioneers. Obstacles and feasibility barriers are high in the early transition phases. Barriers decrease 6 as a result of technical and social learning processes, network building, scale economies, cultural 7 debates, and institutional adjustments. {5.5, 5.6} 8 9 Mitigation policies that integrate and communicate with the values people hold are more 10 successful (high confidence). Values differ between cultures. Measures that support autonomy, energy 11 security and safety, equity and environmental protection, and fairness resonate well in many 12 communities and social groups. Changing from a commercialised, individualised, entrepreneurial 13 training model to an education cognizant of planetary health and human well-being can accelerate 14 climate change awareness and action. {5.4.1, 5.4.2} 15 16 Changes in consumption choices that are supported by structural changes and political action 17 enable the uptake of low-carbon choices (high confidence). Policy instruments applied in 18 coordination can help to accelerate change in a consistent desired direction. Targeted technological 19 change, regulation, and public policy can help in steering digitalisation, the sharing economy, and 20 circular economy towards climate change mitigation. (Box TS.12, Box TS.14) {5.3, 5.6} 21 22 Complementarity in policies helps in the design of an optimal demand-side policy mix (medium 23 confidence). In the case of energy efficiency, for example, this may involve CO2 pricing, standards and 24 norms, and information feedback. {5.3, 5.4, 5.6} 25 26 27 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Technical Summary IPCC AR6 WG III Do Not Cite, Quote or Distribute TS-122 Total pages: 142 1 TS. 6.4 Investment and finance 2 Finance to reduce net GHG emissions and enhance resilience to climate impacts is a critical 3 enabling factor for the low carbon transition. Fundamental inequities in access to finance as well 4 as finance terms and conditions, and countries' exposure to physical impacts of climate change 5 overall, result in a worsening outlook for a global just transition (high confidence). Decarbonising 6 the economy | 184 - 186 | Prot-Adapt-Mitig-Impac | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | 5 Addressing these drivers can enable diverse communities, sectors, stakeholders, regions and cultures to 6 participate in just, equitable and inclusive processes that improve the health and well-being of people 7 and the planet. Looking at climate change from a justice perspective also means placing the emphasis 8 on: i) the protection of vulnerable populations from the impacts of climate change, ii) mitigating 9 the effects of low-carbon transformations, and iii) ensuring an equitable decarbonised world (high 10 confidence). {17.1} The SDG framework25 11 can serve as a template to evaluate the long-term implications of mitigation 12 on sustainable development and vice versa (high confidence). Understanding the co-benefits and 13 trade-offs associated with mitigation is key to understanding how societies prioritise among the 14 various sectoral policy options (medium confidence). Areas with anticipated trade-offs include food 15 and biodiversity, energy affordability/access, and mineral resource extraction. Areas with anticipated 16 co-benefits include health, especially regarding air pollution, clean energy access and water availability. | 197 - 197 | Prot-Adapt-Mitig-Impac | | |

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| IPCC_AR6_WGIII_Full_Report | 26 (Figure TS.22, Figure TS.30) {3.7, 5.2} 27 The timing of mitigation actions and their effectiveness will have significant consequences for 28 broader sustainable development outcomes in the longer term (high confidence). Ambitious 29 mitigation can be considered a precondition for achieving the SDGs. {3.7} 30 Adopting coordinated cross-sectoral approaches to climate mitigation can target synergies and 31 minimise trade-offs, both between sectors and between sustainable development objectives (high 32 confidence). This requires integrated planning using multiple-objective-multiple-impact policy 33 frameworks. Strong inter-dependencies and cross-sectoral linkages create both opportunities for 34 synergies and need to address trade-offs related to mitigation options and technologies. This can only 35 be done if coordinated sectoral approaches to climate change mitigation policies are adopted that 36 mainstream these interactions and ensure local people are involved in the development of new products, 37 as well as production and consumption practices. For instance, there can be many synergies in urban 38 areas between mitigation policies and the SDGs but capturing these depends on the overall planning of 39 urban structures and on local integrated policies such as combining affordable housing and spatial 40 planning with walkable urban areas, green electrification and clean renewable energy (medium 41 confidence). Integrated planning and cross-sectoral alignment of climate change policies are also 42 particularly evident in developing countries' NDCs under the Paris Agreement, where key priority 43 sectors such as agriculture and energy are closely aligned with the proposed mitigation and adaptation 44 actions and the SDGs. {12.6.2, Supplementary Material Table 17.1, 17.3.3} 45 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Technical Summary IPCC AR6 WG III Do Not Cite, Quote or Distribute TS-136 Total pages: 142 1 2 Figure TS.30: Impacts on SDGs of mitigation likely limiting warming to 1.5°C with narrow mitigation 3 policies vs broader sustainable development policies 4 5 Figure TS.30 legend: Left: benefits of mitigation from avoided impacts. Middle: sustainability co-benefits and 6 trade-offs of narrow mitigation policies (averaged over multiple models). Right: sustainability co-benefits and 7 trade-offs of mitigation policies integrating sustainable development goals. Scale: 0% means no change 8 compared to 3°C (left) or current policies (middle and right). Green values correspond to proportional 9 improvements, red values to proportional worsening. Note: only the left panel considers climate impacts on 10 sustainable development; the middle and right panels do not. "Res' C&P" stands for Responsible Consumption 11 and Production (SDG 12). {Figure 3.39} 12 13 The feasibility of deploying response options is shaped by barriers and enabling conditions across 14 geophysical, environmental-ecological, technological, economic, socio-cultural, and institutional 15 dimensions (high confidence). Accelerating the deployment of response options depends on reducing 16 or removing barriers across these dimensions, as well on establishing and strengthening enabling 17 conditions. Feasibility is context-dependent, and also depends on the scale and the speed of 18 implementation. For example: the institutional, legal and administrative capacity to support deployment 19 varies across countries; the feasibility of options that involve large-scale land use changes is highly 20 context dependent; spatial planning has a higher potential in early stages of urban development; the 21 geophysical potential of geothermal is site specific; and cultural and local conditions may either inhibit 22 or enable demand-side responses. Figure TS.31 summarises the | 199 - 202 | Prot-Adapt-Mitig-Impact | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | 26 Recent Assessments (IPCC 2014a, 2018b) began to consider the role of individual behavioural choices 27 and cultural norms in driving energy and food patterns. Notably, SR1.5 (Section 4.4.3 in Chapter 4) 28 outlined emerging evidence on the potential for changes in behaviour, lifestyle and culture to contribute 29 to decarbonisation (and lower the cost); for the first time, AR6 devotes a whole chapter (Chapter 5) to 30 consider these and other underlying drivers of energy demand, food choices and social aspects. | 215 - 215 | | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | 38 1.4.7 Social innovation and behaviour change 39 Social and psychological factors affect both perceptions and behaviour (Whitmarsh et al. 2021; Weber 40 2015). Religion, values, culture, gender, identity, social status and habits strongly influence individual 41 behaviours and choices and therefore, sustainable consumption (Section 1.6.3.1 in this chapter and Section 42 5.2 in Chapter 5). Identities can provide powerful attachments to consumption activities and objects that 43 inhibit shifts away from them (Stoll-Kleemann and Schmidt 2017; Ruby et al. 2020; Brekke et al. 2003; ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 1 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 1-30 Total pages: 106 1 Bénabou and Tirole 2011). Consumption is a habit-driven and social practice rather than simply a set of 2 individual decisions, making shifts in consumption harder to pursue (Evans et al. 2012; Shove and Spurling 3 2013; Kurz et al. 2015; Warde 2017; Verplanken and Whitmarsh 2021). Finally, shifts towards low-carbon 4 behaviour are also inhibited by social-psychological and political dynamics that cause individuals to ignore 5 the connections from daily consumption practices to climate change impacts (Norgaard 2011; Brulle and 6 Norgaard 2019). | 235 - 236 | Impact | INTANBILE | |

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| IPCC_AR6_WGIII_Full_Report | 8 2019; Eshel et al. 2019) however, diets are deeply entrenched in cultures and identities and hard to change 9 (Fresco 2015; Mylan 2018). Changing diets also raises cross-cultural ethical issues, in addition to meat's 10 role in providing nutrition (Plumwood 2004). Henceforth, some behaviours that are harder to change will 11 only be transformed by the transition itself: triggered by policies, the transition will bring about 12 technologies that, in turn, will entrench new sustainable behaviours. | 236 - 236 | | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | 25 Source: IPCC 2018b 26 27 Other concepts such as "Doughnut Economics" (Raworth 2018), ecological modernisation, and 28 mainstreaming are also used to convey ideals of development pathways that take sustainability, climate 29 mitigation, and environmental limits seriously (Dale et al. 2015a). Mainstreaming focuses on ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 1 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 1-41 Total pages: 106 1 incorporating climate change into national development activities, such as the building of infrastructure 2 (Wamsler and Pauleit 2016; Runhaar et al. 2018). The 'green economy' and green growth – growth 3 without undermining ecological systems, partly by gaining economic value from cleaner technologies 4 and systems and is inclusive and equitable in its outcomes - has gained popularity in both developed 5 and developing countries as an approach for harnessing economic growth to address environmental 6 issues (Bina 2013; Georgeson et al. 2017; Capasso et al. 2019; Song et al. 2020; Hao et al. 2021). Critics 7 however argue that green economy ultimately emphasises economic growth to the detriment of other 8 important aspects of human welfare such as social justice (Adelman 2015; Death 2014; Kamuti 2015), 9 and challenge the central idea that it is possible to decouple economic activity and growth (measured 10 as GDP increment) from increasing use of biophysical resources (raw materials, energy) (Jackson and 11 Victor 2019; Parrique et al. 2019; Hickel and Kallis 2020; Haberl et al. 2020; Vadén et al. 2020). | 246 - 247 | Prot-Adapt-Mitig- | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | 5 6 2.5.3.3 Granular technologies improve faster 7 The array of evidence of technology learning that has accumulated both before and since AR5 8 (Thomassen et al., 2020) has prompted investigations about the factors that enable rapid technology 9 learning. From the wide variety of factors considered, unit size has generated the strongest and most 10 robust results. Smaller unit sizes, sometimes referred to as 'granularity', tend to be associated with faster 11 learning rates (medium confidence) (Sweerts et al., 2020; Wilson et al., 2020). Examples include solar 12 PV, batteries, heat pumps, and to some extent wind power. The explanatory mechanisms for these 13 observations are manifold and well established: more iterations are available with which to make 14 improvements (Trancik, 2006); mass production can be more powerful than economies of scale 15 (Dahlgren et al., 2013); project management is simpler and less risky (Wilson et al., 2020); the ease of 16 early retirement can enable risk-taking for innovative designs (Sweerts et al., 2020); and they tend to 17 be less complicated (Malhotra and Schmidt, 2020; Wilson et al., 2020). Small technologies often 18 involve iterative production processes with many opportunities for learning by doing and have much of 19 the most advanced technology in the production equipment than in the product itself. In contrast, large 20 unit scale technologies – such as full-scale nuclear power, CCS, low-carbon steel making, and negative 21 emissions technologies such as bioenergy with carbon capture and sequestration (BECCS) – are often 22 primarily built on site and include thousands to millions of parts such that complexity and system 23 integration issues are paramount (Nemet, 2019). Despite the accumulating evidence of the benefits of 24 granularity, these studies are careful to acknowledge the role of other factors in explaining learning. In 25 a study of 41 energy technologies (Figure 2.23), unit size explained 22% of the variation in learning 26 rates (Sweerts et al., 2020) and a study of 31 low-carbon technologies showed unit size explained 33% 27 (Wilson et al., 2020). Attributing that amount of variation to a single factor is rare in studies of 28 technological change. The large residual has motivated studies, which find that small-scale technologies 29 provide opportunities for rapid change, but they do not make rapid change inevitable; a supportive 30 context, including supportive policy and complementary technologies, can stimulate more favourable 31 technology outcomes (high confidence). | 371 - 371 | Impact | | |

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| IPCC_AR6_WGIII_Full_Report | 4 Status Competition. As part of a larger consumer society and consumer culture, based on consumer- 5 oriented lifestyles, products frequently provide a source for identity and fulfilment (Stearns, 2001; 6 Baudrillard, 2017; Jorgenson et al., 2019). People pursue cultural constructs such as status, comfort, 7 convenience, hygiene, nutrition, and necessity. Consumption is, by and large, not an end in itself but a 8 means to achieve some other end, and those ends are diverse and not necessarily connected to one 9 another (Wilk, 2010). This shows that consumption patterns cannot be sufficiently understood without 10 also considering the context, for example the cultural and social contexts leading to status competition 11 and status-related consumption (Veblen, 2009; Schor and J.B., 2015; Wilk, 2017). Status seeking can 12 work to reduce emissions when 'green products' such as an electric car or photovoltaics on the roof 13 become a sign for high-status (Griskevicus Tybur, and Van Den Bergh, 2010). It also can work to 14 increase emissions through visible and high-carbon intensive consumption items such a larger homes, 15 fuel-inefficient SUVs cars, and long-distance vacations (Schor, 1998), driven by a notion of having 'to 16 keep up with the Joneses'(Hamilton, 2011). This can lead to formation of new habits and needs, where 17 products and services become normalized and are quickly perceived as needed, reinforced through 18 social networks and advertisement, making it psychologically easy to convert a luxury item to a 19 perceived necessity (Assadour, 2012). For example, the share of adults who consider a microwave a 20 necessity was about one third in 1996 but had increased to more than two thirds in 2006, but retreated 21 in importance during the recession years 2008-2009 (Morin and Taylor, 2009). Similar ups and downs 22 have been observed for television sets, air conditioning, dishwasher or the clothes dryer. (Druckman 23 and Jackson, 2009). What is considered a basic need and what is a luxury is subject to change over 24 one's lifetime and in relation to others (Horowitz, 1988). This shows that the boundaries of public's 25 luxury-versus-necessity perceptions are malleable (Morin and Taylor, 2009). | 379 - 379 | Impact | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | 26 Inequality. Global inequality within and between countries has shifted over the last decades expanding 27 consumption and consumer culture (Castilhos and Fonseca, 2016; Alvaredo et al., 2018; Short and 28 Martínez, 2020). The rise of middle class income countries, mostly in Asia, eg. China, India, Indonesia 29 and Vietnam, and the stagnating incomes of the middle classes in developed economies reduced 30 between countries income differences; meanwhile the population under extreme poverty (threshold of 31 1.9 USD per person/day) is now concentrated in Sub-Saharan Africa and South Asia (Milanović, 2016). | 379 - 379 | | | |

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| IPCC_AR6_WGIII_Full_Report | 9 Sources: (Luderer et al., 2018; Tong et al., 2019) Future CO2 emissions from existing and planned fossil fuel infrastructure (accounting studies) Residual fossil fuel emissions - cumulative gross CO2 emissions from fossil fuel and industry until reaching net zero CO2 emissions (in GtCO2) Tong et al. (2019) Early strengthening from (2020) Delayed strengthening from 2030 GtCO2 Year Well below 2°C Below 1.5°C in 2100 Well below 2°C Below 1.5°C in 2100 Existing AND proposed Electricity 550 Existing AND future instalments Electricity 180 130 250 200 (380-730) 2018 (140 - 310) (90 - 160) (220 - 340) (190 - 230) Non-electric supply Non-electric supply 100 59 120 75 (42 - 130) (27 - 83) (55 - 150) (40 - 100) Existing Industry 160 Industry 260 140 290 200 (110-220) 2017 (160 - 330) (86 - 180) (200 - 370) (130 - 250) Transportation 64 Transportation 310 170 310 200 (53-75) 2017 (190 - 370) (110 - 220) (250 - 400) (140 - 260) Buildings 74 Buildings 110 58 120 73 (52-110) 2018 (75 - 110) (35 - 77) (80 - 150) (51 - 93) All sectors and proposed electricity 850 All sectors (2021 – net zero CO2) 960 570 1100 770 (730 - 1100) (400 - 640) (900 - 1200) (590 - 860) All sectors (2021-2100) 1300 850 1400 1000 (600-1,100) (970 - 1500) (650 - 1100) (1200 - 1600) (860 - 1300) Implied minimum requirement for carbon dioxide removal until 2100 150 (0 – 350) 350 (150 – 600) 250 (50 – 450) 500 (360 – 800) 10 ACCEPTED VERSION SUBJECT TO FINAL EDITS Final Government Distribution Chapter 2 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 2-76 Total pages: 127 1 2 2.8 Climate and Non-Climate Policies and Measures and their Impacts on 3 Emissions 4 2.8.1 Introduction 5 The key to achieving climate change mitigation targets includes crafting environmentally effective, 6 economically efficient and socially equitable policies. For the purposes of this section, policies are 7 defined broadly as actions to guide decisions to reach explicit goals and, accordingly, climate 8 (mitigation) policies are the ones whose primary objective is to reduce GHG emissions. They include a 9 range of domains from economic and institutional to R&D and social policies and are implemented by 10 various instruments (e.g., market-based and regulatory in the economic domain) and measures (e.g., 11 legal provisions and governance arrangements in the institutional domain) (see Chapter 13 and the 12 Glossary about mitigation policies). Yet GHG emissions are also affected by policies enacted in various 13 social, economic, and environmental areas to pursue primarily non-climatic objectives. This section 14 presents succinct assessments of the outcomes and effectiveness of a few selected policy instruments 15 applied in the last two decades targeting climate protection (Sections 2.8.2 and 2.8.3) and GHG 16 emissions impacts of selected other policies primarily aiming improvements in environmental quality and natural resource management (Section 2.8.4).12 17 18 It is rather difficult, though not impossible, to discern the genuine impacts of climate and non-climate 19 policies on GHG emissions. Most of current and past policies target only a small part of global emissions 20 in a limited geographical area and/or from a small number of economic sectors. However, in addition to 21 the targeted region or sector, policies and measures tend to affect GHG emissions in other parts of the 22 world. Emissions leakage is the key channel by which such phenomena and complex interactions occur. 23 13 Uncertainties in impacts, synergies, and trade-offs between policies and measures also 24 complicate the evaluation of emissions impacts. These make it challenging to identify the impacts of 25 any specific policy or measure on emissions of any specific region or sector. Rigorous statistical analyses 26 are necessary for building strong empirical evidence, but the | 387 - 388 | Prot-Adapt-Mitig-Impact | | |
| IPCC_AR6_WGIII_Full_Report | 12 Forestry case: zero deforestation 13 Forest is generally defined as land spanning more than 0.5 hectares with trees higher than 5 meters and 14 a canopy cover of more than 10%, or trees able to reach these thresholds in situ (FAO, 1998). Zero- 15 deforestation (i.e., both gross and net zero deforestation) initiatives generate results at multiple levels 16 (Meijer, 2014). Efforts to achieve zero-deforestation (and consequently emissions) are announced by 17 NGOs, companies, governments, and other stakeholder groups. NGOs engage through their 18 campaigning, but also propose tools and approaches for companies (Leijten et al., 2020). The extent to 19 which companies can actually monitor actions conducive to zero-deforestation pledges depends on their 20 position in the supply chain. Beyond the business practices of participating companies, achieving long- 21 term positive societal impacts requires upscaling from supply chains towards landscapes, with 22 engagement of all stakeholders, and in particular small producers. The various success indicators for 23 zero deforestation mirror the multiple levels at which such initiatives develop: progress towards 24 certification, improved traceability, and legality are apparent output measures, whereas direct-area 25 monitoring and site selection approaches target the business practices themselves. | 393 - 393 | Impact | | |

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| IPCC_AR6_WGIII_Full_Report | 44 45 3.3.2.3 The timing of net zero emissions 46 47 In addition to the constraints on change in global mean temperature, the Paris Agreement also calls for 48 reaching a balance of sources and sinks of GHG emissions (Art. 4). Different interpretations of the 49 concept related to balance have been published (Rogelj et al. 2015c; Fuglestvedt et al. 2018). Key 50 concepts include that of net zero CO2 emissions (anthropogenic CO2 sources and sinks equal zero) 51 and net zero greenhouse gas emission (see also Annex I Glossary and Box 3.3). The same notion can 52 be used for all GHG emissions, but here ranges also depend on the use of equivalence metrics 53 (Chapter 2, Box 2.2). Moreover, it should be noted that while reaching net zero CO2 emissions 54 typically coincides with the peak in temperature increase; net zero GHG emissions (based on GWP- 55 100) implies a decrease in global temperature (Riahi et al. 2021) and net zero GHG emission typically ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 3 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 3-37 Total pages: 156 1 requires negative CO2 emissions to compensate for the remaining emissions from other GHGs. Many 2 countries have started to formulate climate policy in the year that net zero emissions (either CO2 or all 3 greenhouse gases) are reached – although, at the moment, formulations are often still vague (Rogelj et 4 al. 2021). There has been increased attention on the timing of net zero emissions in the scientific 5 literature and ways to achieve it. | 475 - 476 | | | |
| IPCC_AR6_WGIII_Full_Report | 6 2018a), while others do not—citing concerns around its feasibility due to limited potential sites and 7 issues related to socio-political acceptance—, and rather point to very ambitious increase in renewable 8 energy, which in turn could pose significant challenges in systematically integrating renewable energy 9 into the current energy systems (Viebahn et al. 2014; Mathur and Shekhar 2020). Some limitations of 10 CCS, including uncertain costs, lifecycle and net emissions, other biophysical resource needs, and social 11 acceptance are acknowledged in existing studies (Sekera and Lichtenberger 2020; Jacobson 12 2019;Viebahn et al. 2014; Mathur and Shekhar 2020) 13 While national mitigation portfolios aiming at net zero emissions or lower will need to include some 14 level of CDR, the choice of methods and the scale and timing of their deployment will depend on the 15 ambition for gross emission reductions, how sustainability and feasibility constraints are managed, and 16 how political preferences and social acceptability evolve (Cross-Chapter Box 8). Furthermore, 17 mitigation deterrence may create further uncertainty, as anticipated future CDR could dilute incentives 18 to reduce emissions now (Grant et al. 2021), and the political economy of net negative emissions has 19 implications for equity (Mohan et al. 2021). | 640 - 640 | Prot-Adapt-Mitig- | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | 23 Obstacles to the implementation of accelerated mitigation pathways can be grouped in four main 24 categories (Table 4.10). The first set of arguments can be understood through the lens of cost-benefit 25 analysis of decision-makers, as they revolve around the following question: Are costs too high relative 26 to benefits? More precisely, are the opportunity costs—in economics terms, what is being forfeited by 27 allocating scarce resources to mitigation—justified by the benefits for the decision-maker (whether 28 individual, firm, or nation)? This first set of obstacles is particularly relevant because accelerated 29 mitigation pathways imply significant effort in the short-run, while benefits in terms of limited warming 30 accrue later and almost wholly to other actors. However, as discussed in 3.6 and 4.2.6, mitigation costs 31 for a given mitigation target are not carved in stone. They strongly depend on numerous factors, 32 including the way mitigation policies have been designed, selected, and implemented, the processes 33 through which markets have been shaped by market actors and institutions, and nature of socially- and 34 culturally-determined influences on consumer preferences. Hence, mitigation choices that might be 35 expressed straightforwardly as techno-economic decisions are, at a deeper level, strongly conditioned 36 by underlying structures of society. | 653 - 653 | Prot-Adapt-Mitig- | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | 35 Addressing these choices coherently shifts the development pathway away from a continuation of 36 existing trends, 37 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 4 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 4-64 Total pages: 156 1 2 Figure 4.7 Shifting development pathways to increased sustainability: Choices by a wide range of actors 3 at key decision points on development pathways can reduce barriers and provide more tools to accelerate 4 mitigation and achieve other Sustainable Development Goals 5 4.3.1.3 Expanding the range of policies and other mitigative options 6 Shifting development pathways aims to influence the ultimate drivers of emissions (and development 7 generally), such as the systemic and cultural determinants of consumption patterns, the political systems 8 and power structures that govern decision making, the institutions and incentives that guide and 9 constrain socio-technical innovation, and the norms and information platforms that shape knowledge 10 and discourse, and culture, values and needs (Raskin et al. 2002). These ultimate drivers determine the 11 mitigative capacity of a society. | 658 - 659 | Prot-Adapt-Mitig- | INTANBILE | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGIII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 4 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 4-75 Total pages: 156 1 2a. Past development pathways determine both today's GHG emissions and the set of opportunities 2 to reduce emissions 3 4 Development pathways drive GHG emissions for a large part (2.4, 2.5 and 2.6). For example, different 5 social choices and policy packages with regard to land use and associated rents will result in human 6 settlements with different spatial patterns, different types of housing markets and cultures, and different 7 degrees of inclusiveness, and thus different demand for transport services and associated GHG 8 emissions (8.3.1, 10.2.1). | 669 - 670 | | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | 33 Because low-carbon transitions are political processes, analyses are needed of policy as well as for 34 policy (13.6). Political scientists have developed a number of theoretical models that both explain 35 policy-making processes and provide useful insights for influencing those processes. Case studies of 36 successes and failures in sustainable development and mitigation offer equally important insights. Both 37 theoretical and empirical analysis reinforce the argument that single policy instruments are not 38 sufficient (robust evidence, high agreement). Policymakers might rather mobilise a range of policies, 39 such as financial instruments (taxes, subsidies, grants, loans), regulatory instruments (standards, laws, 40 performance targets) and processual instruments (demonstration projects, network management, public 41 debates, consultations, foresight exercises, roadmaps) (Voß et al. 2007). Policies can be designed to 42 focus on limiting or phasing out high-carbon technology. The appropriate mix is likely to vary between 43 countries and domains, depending on political cultures and stakeholder configurations (Rogge and 44 Reichardt 2016), but is likely to include a combination of: a) standards, nudges and information to 45 encourage low-carbon technology adoption and behavioural change; b) economic incentives to reward 46 low carbon investments; c) supply-side policy instruments including for fossil fuel production (to ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 4 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 4-82 Total pages: 156 1 complement demand-side climate policies) and d) innovation support and strategic investment to 2 encourage systemic change (Grubb 2014). These approaches can be mutually reinforcing. For example, 3 carbon pricing can incentivise low carbon innovation, while targeted support for emerging niche 4 technologies can make them more competitive encourage their diffusion and ultimately facilitate a 5 higher level of carbon pricing. Similarly, the success of feed-in tariffs in Germany only worked as well 6 as it did because it formed part of a broader policy mix including "supply-push" mechanisms such as 7 subsidies for research and "systemic measures" such as collaborative research projects and systems of 8 knowledge exchange (Rogge et al. 2015). | 676 - 677 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGIII_Full_Report | 7 Restoration or protection of coastal ecosystems is an important adaptation action with multiple benefits, 8 with bounded global mitigation benefits (Gattuso et al. 2018; Bindoff et al. 2019). Such 9 restoration/preservation reduces coastal erosion and protects from storm surges, and otherwise mitigates 10 impacts of sea level rise and extreme weather along the coast line (Siikamäki et al. 2012; Romañach et 11 al. 2018; Alongi 2008). Restoration of tidal flow to coastal wetlands inhibits methane emissions which 12 occur in fresh and brackish water (Kroeger et al. 2017) (7.4.2.8 describes a more inclusive set of 13 ecosystem services provided by coastal wetlands). Coastal habitat restoration projects can also provide 14 significant social benefits in the form of job creation (through tourism and recreation opportunities), as 15 well as ecological benefits through habitat preservation (Edwards et al. 2013; Sutton-Grier et al. 2015; 16 Sutton-Grier and Moore 2016; Kairo et al. 2018; Wylie et al. 2016; Bindoff et al. 2019). | 691 - 691 | Prot-Adapt-Mitig-Impa | INTANBILE | |

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| IPCC_AR6_WGIII_Full_Report | 47 Claims on the benefits of the circular economy for sustainability and climate change mitigation have 48 limited evidence. {5.3.4, 5.3.4.1, 5.3.4.2, Figure 5.12, Figure 5.13} 49 ACCEPTED VERSION SUBJECT TO FINAL EDITS Final Government Distribution Chapter 5 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 5-4 Total pages: 192 1 Social aspects of demand-side mitigation actions 2 3 Decent living standards (DLS) and well-being for all are achievable through the implementation 4 of high-efficiency low demand mitigation pathways (medium confidence). Decent Living Standards 5 (DLS) – a benchmark of material conditions for human well-being – overlaps with many Sustainable 6 Development Goals (SDGs). Minimum requirements of energy use consistent with enabling well-being for all is between 20 and 50 GJ cap-1 yr-1 7 depending on the context. {5.2.2.1, 5.2.2.2, Box 5.3} 8 9 Providing better services with less energy and resource input has high technical potential and is 10 consistent with providing well-being for all (medium confidence). Assessment of 19 demand-side 11 mitigation options and 18 different constituents of well-being show that positive impacts on well-being 12 outweigh negative ones by a factor of 11. {5.2, 5.2.3, Figure 5.6,} 13 14 Demand-side mitigation options bring multiple interacting benefits (high confidence). Energy 15 services to meet human needs for nutrition, shelter, health, etc. are met in many different ways with 16 different emissions implications that depend on local contexts, cultures, geography, available 17 technologies, social preferences. In the near term, many less-developed countries and poor people 18 everywhere require better access to safe and low-emissions energy sources to ensure decent living 19 standards and increase energy savings from service improvements by about 20-25%. {5.2, 5.4.5, Figure 20 5.3, Figure 5.4, Figure 5.5, Figure 5.6, Box 5.2, Box 5.3} 21 22 Granular technologies and decentralized energy end-use, characterised by modularity, small unit 23 sizes and small unit costs, diffuse faster into markets and are associated with faster technological 24 learning benefits, greater efficiency, more opportunities to escape technological lock-in, and 25 greater employment (high confidence). Examples include solar photovoltaic systems, batteries, and 26 thermal heat pumps. {5.3, 5.5, 5.5.3} 27 28 Wealthy individuals contribute disproportionately to higher emissions and have a high potential 29 for emissions reductions while maintaining decent living standards and well-being (high 30 confidence). Individuals with high socio-economic status are capable of reducing their GHG emissions 31 by becoming role models of low-carbon lifestyles, investing in low-carbon businesses, and advocating 32 for stringent climate policies. {5.4.1, 5.4.3, 5.4.4, Figure 5.14} 33 34 Demand-side solutions require both motivation and capacity for change (high confidence). | 754 - 755 | Prot-Adapt-Mitig-Impac | INTANBILE | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGIII_Full_Report | 47 {5.4.3} 48 49 Social influencers and thought leaders can increase the adoption of low-carbon technologies, 50 behaviours, and lifestyles (high confidence). Preferences are malleable and can align with a cultural ACCEPTED VERSION SUBJECT TO FINAL EDITS Final Government Distribution Chapter 5 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 5-6 Total pages: 192 1 shift. The modelling of such shifts by salient and respected community members can help bring about 2 changes in different service provisioning systems. Between 10% and 30% of committed individuals are 3 required to set new social norms. {5.2.1, 5.4} 4 5 Preconditions and instruments to enable demand-side transformation 6 7 Social equity reinforces capacity and motivation for mitigating climate change (medium 8 confidence). Impartial governance such as fair treatment by law and order institutions, fair treatment 9 by gender, and income equity, increases social trust, thus enabling demand-side climate policies. High 10 status (often high carbon) item consumption may be reduced by taxing absolute wealth without 11 compromising well-being. {5.2, 5.4.2, 5.6} 12 13 Policies that increase the political access and participation of women, racialized, and marginalised 14 groups, increase the democratic impetus for climate action. (high confidence). Including more 15 differently situated knowledge and diverse perspectives makes climate mitigation policies more 16 effective. {5.2, 5.6} 17 18 Carbon pricing is most effective if revenues are redistributed or used impartially (high 19 confidence). A carbon levy earmarked for green infrastructures or saliently returned to taxpayers 20 corresponding to widely accepted notions of fairness increases the political acceptability of carbon 21 pricing. {5.6, Box 5.11} 22 23 Greater contextualisation and granularity in policy approaches better addresses the challenges 24 of rapid transitions towards zero-carbon systems (high confidence). Larger systems take more time 25 to evolve, grow, and change compared to smaller ones. Creating and scaling up entirely new systems 26 takes longer than replacing existing technologies and practices. Late adopters tend to adopt faster than 27 early pioneers. Obstacles and feasibility barriers are high in the early transition phases. Barriers decrease 28 as a result of technical and social learning processes, network building, scale economies, cultural 29 debates, and institutional adjustments. {5.5, 5.6} 30 31 The lockdowns implemented in many countries in response to the COVID-19 pandemic 32 demonstrated that behavioural change at a massive scale and in a short time is possible (high 33 confidence). COVID-19 accelerated some specific trends, such as an uptake in urban cycling. However, 34 the acceptability of collective social change over a longer term towards less resource-intensive lifestyles 35 depends on social mandate building through public participation, discussion and debate over 36 information provided by experts, to produce recommendations that inform policy-making. {Box 5.2} 37 38 Mitigation policies that integrate and communicate with the values people hold are more 39 successful (high confidence). Values differ between cultures. Measures that support autonomy, energy 40 security and safety, equity and environmental protection, and fairness resonate well in many 41 communities and social groups. Changing from a commercialised, individualised, entrepreneurial 42 training model to an education cognizant of planetary health and human well-being can accelerate 43 climate change awareness and action {5.4.1, 5.4.2} 44 45 Changes in consumption choices that are supported by structural changes and political action 46 enable the uptake of low-carbon choices (high confidence). Policy instruments applied in 47 coordination can help to accelerate change in a consistent desired direction. Targeted technological 48 change, regulation, and public policy | 756 - 759 | Prot-Adapt-Mitig-Impa | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | 31 2014). In this chapter, service-related mitigation strategies are categorized as Avoid, Shift, or Improve 32 (ASI) options to show how mitigation potentials, and social groups who can deliver them, are much 33 broader than usually considered in traditional sector-specific presentations. ASI originally arose from 34 the need to assess the staging and combinations of interrelated mitigation options in the provision of 35 transportation services (Hidalgo and Huizenga 2013). In the context of transportation services, ASI 36 seeks to mitigate emissions through avoiding as much transport service demand as possible (e.g., 37 telework to eliminate commutes, mixed-use urban zoning to shorten commute distances), shifting 38 remaining demand to more efficient modes (e.g., bus rapid transit replacing passenger vehicles), and 39 improving the carbon intensity of modes utilised (e.g., electric buses powered by renewables) (Creutzig 40 et al. 2016a). This chapter summarises ASI options and potentials across sectors and generalises the 41 definitions. 'Avoid' refers to all mitigation options that reduce unnecessary (in the sense of being not 42 required to deliver the desired service output) energy consumption by redesigning service provisioning 43 systems; 'shift' refers to the switch to already existing competitive efficient technologies and service 44 provisioning systems; and 'improve' refers to improvements in efficiency in existing technologies. The 45 Avoid-Shift-Improve framing operates in three domains: 'Socio-cultural', where social norms, culture, 46 and individual choices play an important role – a category especially but not only relevant for avoid 47 options; 'Infrastructure', which provides the cost and benefit landscape for realising options and is 48 particularly relevant for shift options; and 'Technologies', especially important for the improve options. | 760 - 760 | Prot-Adapt-Mitig- | INTANBILE | |

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| --- | --- | --- | --- | --- | --- |
| IPCC_AR6_WGIII_Full_Report | 49 Avoid, Shift, and Improve choices will be made by individuals and households, instigated by salient 50 and respected role models and novel social norms, but require support by adequate infrastructures ACCEPTED VERSION SUBJECT TO FINAL EDITS Final Government Distribution Chapter 5 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 5-10 Total pages: 192 1 designed by urban planners and building and transport professionals, corresponding investments, and a 2 political culture supportive of mitigation action. This is particularly true for many Avoid and Shift 3 decisions that are difficult because they encounter psychological barriers of breaking routines, habits 4 and imagining new lifestyles and the social costs of not conforming to society (Kaiser 2006). Simpler 5 Improve decisions like energy efficiency investments on the other hand can be triggered and sustained 6 by traditional policy instruments complemented by behavioural nudges. | 760 - 761 | Prot-Adapt-Mitig- | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | 40 nutrition, shelter, health, etc.), recognising that these service needs may be met in many different ways 41 (with different emissions implications) depending on local contexts, cultures, geography, available 42 technologies, social preferences, and other factors. Therefore, one key way of thinking about providing 43 well-being for all with low carbon emissions centres around prioritising ways of providing services for 44 DLS in a low-carbon way (including choices of needs satisfiers, and how these are provided or made 45 accessible). They may be supplied to individuals or groups / communities, both through formal markets 46 and/or informally, e.g. by collaborative work, in coordinated ways that are locally-appropriate, designed 47 and implemented in accordance with overlapping local needs. | 768 - 768 | | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | 2 2019b; Millward-Hopkins et al. 2020), which shows the level of inequality that exists; this depends on 3 the context such as geography, culture, infrastructure or how services are provided (Brand-Correa et al. | 771 - 771 | | | |
| IPCC_AR6_WGIII_Full_Report | 47 2020; Stratford 2020; Otto et al. 2019) (see Section 5.2.2.3). Conspicuous consumption by the wealthy 48 is the cause of a large proportion of emissions in all countries, related to expenditures on such things as 49 air travel, tourism, large private vehicles and large homes (Brand and Boardman 2008; Brand and ACCEPTED VERSION SUBJECT TO FINAL EDITS Final Government Distribution Chapter 5 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 5-30 Total pages: 192 1 Preston 2010; Gore 2015; Sahakian 2018; Osuoka and Haruna 2019; Lynch et al. 2019; Roy and Pal 2 2009; Hubacek et al. 2017; Jorgenson et al. 2017; Gössling 2019; Kenner 2019; Roy et al. 2012). | 780 - 781 | | | |
| IPCC_AR6_WGIII_Full_Report | 10 Women's work and decision-making are central in the food chain and agricultural output in most 11 developing countries, and in household management everywhere. Emissions from cooking fuels can 12 cause serious health damages, and unsustainable extraction of biofuels can also hurt mitigation (Bailis 13 et al. 2015), so considering health, biodiversity and climate tr adeoffs and co-benefits is important 14 (Rosenthal et al. 2018; Aberilla et al. 2020; Mazorra et al. 2020) . Policies on energy use and 15 consumption are often focused on technical issues related to energy supply, thereby overlooking 16 'demand-side' factors such as household decision-making, unpaid work, livelihoods and care 17 (Himmelweit 2002; Perch 2011; Fumo 2014; Hans et al. 2019; Huyer and Partey 2020). Such gender- 18 blindness represents the manifestation of wider issues related to political ideology, culture and tradition 19 (Carr and Thompson 2014; Thoyre 2020; Perez et al. 2015; Fortnam et al. 2019). | 786 - 786 | Prot-Adapt-Mitig-Impac | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | 6 7 8 9 Figure 5.7 Demand-side mitigation options and indicative potentials 10 Mitigation response options related to demand for services have been categorised into three domains: 11 'socio-cultural factors', related to social norms, culture, and individual choices and behaviour; 12 'infrastructure use', related to the provision and use of supporting infrastructure that enables individual 13 choices and behaviour; and 'technology adoption', which refers to the uptake of technologies by end 14 users. Potentials in 2050 are estimated using the International Energy Agency's 2020 World Energy 15 Outlook STEPS (Stated Policy Scenarios) as a baseline. This scenario is based on a sector-by-sector 16 assessment of specific policies in place, as well as those that have been announced by countries by mid- 17 2020. This scenario was selected due to the detailed representation of options across sectors and sub- 18 sectors. The heights of the coloured columns represent the potentials on which there is a high level of 19 agreement in the literature, based on a range of case studies. The range shown by the dots connected by 20 dotted lines represents the highest and lowest potentials reported in the literature which have low to 21 medium levels of agreement. The demand side potential of socio-cultural factor in food has two parts. | 793 - 793 | Prot-Adapt-Mitig- | INTANBILE | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGIII_Full_Report | 13 14 15 5.4 Transition toward high well-being and low-carbon demand societies 16 Demand-side mitigation involves individuals (e.g. consumption choices), culture (e.g. social norms, 17 values), corporate (e.g. investments), institutions (e.g. political agency), and infrastructure change (high 18 evidence, high agreement). These five drivers of human behaviour either contribute to the status-quo of 19 a global high-carbon, consumption, and GDP growth oriented economy or help generate the desired 20 change to a low-carbon energy-services, well-being, and equity oriented economy (Jackson 2017; 21 Cassiers et al. 2018; Yuana et al. 2020)(Figure 5.14). Each driver has novel implications for the design 22 and implementation of demand-side mitigation policies. They show important synergies, making energy 23 demand mitigation a dynamic problem where the packaging and/or sequencing of different policies play 24 a role in their effectiveness, demonstrated in Sections 5.5 and 5.6. The Social Science Primer 25 (Supplementary Material I Chapter 5) describes theory and empirical insights about the interplay 26 between individual agency, the social and physical context of demand-side decisions in the form of 27 social roles and norms, infrastructure and technological constraints and affordances, and other formal 28 and informal institutions. Incremental interventions on all five fronts change social practices, effecting 29 simultaneously energy and well-being (Schot and Kanger 2018). Transformative change will require 30 coordinated use of all five drivers, as described in Figure 5.14 and Table 5. using novel insights about 31 behaviour change for policy design and implementation (high evidence, high agreement). In particular, 32 socio-economic factors, such as equity, public service quality, electricity access and democracy are 33 found to be highly significant in enabling need satisfaction at low energy use, whereas economic growth 34 beyond moderate incomes and extractive economic activities are observed to be prohibiting factors 35 (Vogel et al. 2021). | 818 - 818 | Prot-Adapt-Mitig-Impac | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | 14 15 START BOX 5.6 HERE 16 17 Box 5.6 Socio-behavioural aspects of deploying cookstoves 18 Universal access to clean and modern cooking energy could cut premature death from household air 19 pollution by two-thirds, while reducing forest degradation and deforestation and contribute to the 20 reduction of up to 50% of CO2 emissions from cooking (relative to baseline by 2030) (IEA 2017c; Hof 21 et al. 2019). However, in the absence of policy reform and substantial energy investments, 2.3 billion 22 people will have no access to clean cooking fuels such as biogas, LPG, natural gas or electricity in 2030 23 (IEA 2017c). Studies reveal that a combination of drivers influence adoption of new cookstove 24 appliances including affordability, behavioural and cultural aspects (lifestyles, social norms around 25 cooking and dietary practices), information provision, availability, aesthetic qualities of the technology, 26 perceived health benefits and infrastructure (spatial design of households and cooking areas). The 27 increasing efficiency improvements in electric cooking technologies, could enable households to shift 28 to electrical cooking at mass scale. The use of pressure cookers and rice cookers is now widespread in 29 South Asia and beginning to penetrate the African market as consumer attitudes are changing towards 30 household appliances with higher energy efficiencies (Batchelor et al. 2019). Shifts towards electric and 31 LPG stoves in Bhutan (Dendup and Arimura 2019), India (Pattanayak et al. 2019), Ecuador (Martínez 32 et al. 2017; Gould et al. 2018) and Ethiopia (Tesfamichael et al. 2021); and improved biomass stoves in 33 China (Smith et al. 1993). Significant subsidy, information (Dendup and Arimura 2019), social 34 marketing and availability of technology in the local markets are some of the key policy instruments 35 helping to adopt ICS (Pattanayak et al. 2019). There is no one-size-fits-all solution to household air 36 pollution – different levels of shift and improvement occur in different cultural contexts, indicating the 37 importance of socio-cultural and behavioural aspects in shifts in cooking practices. See more in 38 Supplementary Material Chapter 5, SM5.6.2. | 821 - 821 | | | |
| IPCC_AR6_WGIII_Full_Report | 7 8 Core values also influence which costs and benefits are considered (Hahnel et al. 2015; Gölz and Hahnel 9 2016; Steg 2016). Information provision and appeals are thus more effective when tailored to those 10 values (Bolderdijk et al. 2013; Boomsma and Steg 2014), as implemented by the energy-cultures 11 framework (Stephenson et al. 2015; Klaniecki et al. 2020). Awareness, personal norms, and perceived 12 behavioural control predict willingness to change energy-related behaviour above and beyond 13 traditional sociodemographic and economic predictors (Schwartz 1977; Ajzen 1985; Stern 2000), as do 14 perceptions of self-efficacy (Bostrom et al. 2019). However, such motivation for change is often not 15 enough, as actors also need capacity for change and help to overcome individual, institutional and 16 market barriers (Young et al. 2010; Carrington et al. 2014; Bray et al. 2011). | 822 - 822 | Impact | INTANBILE | |

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| IPCC_AR6_WGIII_Full_Report | 26 27 5.4.4 Institutional Drivers 28 The allocation of political power to incumbent actors and coalitions has contributed to lock-in of 29 particular institutions, stabilising the interests of incumbents through networks that include 30 policymakers, bureaucracies, advocacy groups and knowledge institutions (high agreement, high 31 evidence). There is high evidence and high agreement in that institutions are central in addressing 32 climate change mitigation. Indeed, social provisioning contexts including equity, democracy, public 33 services and high quality infrastructure are found to facilitate high levels of need satisfaction at lower 34 energy use, whereas economic growth beyond moderate incomes and dependence on extractive 35 industries inhibit it (Vogel et al. 2021). They shape and interact with technological systems (Unruh 36 2000; Foxon et al. 2004; Seto et al. 2014) and represent rules, norms and conventions that organise and 37 structure actions (Vatn 2015) and help create new path dependency or strengthen existing path 38 dependency (Mattioli et al. 2020) (also see case studies in Box 5.5-5.8 and Supplementary Material 39 Chapter 5). These drive behaviour of actors through formal (e.g., laws, regulations, and standards) or 40 informal (e.g., norms, habits, and customs) processes, and can create constraints on policy options 41 (Breukers and Wolsink 2007). For example, 'the car dependent transport system' is maintained by 42 interlocking elements and institutions, consisting of i) the automotive industry; ii) the provision of car 43 infrastructure; iii) the political economy of urban sprawl; iv) the provision of public transport; v) 44 cultures of car consumption (Mattioli et al. 2020). The behaviour of actors, their processes and 45 implications on policy options and decisions is discussed further in Section 5.6. | 836 - 836 | Prot-Adapt-Mitig- | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | 8 9 From a welfare point of view, infrastructure investments are not constrained by revealed or stated 10 preferences (high evidence, high agreement). Preferences change with social and physical environment, 11 and infrastructure interventions can be justified by objective measures, such as public health and climate 12 change mitigation, not only given preferences (high agreement, high evidence). Specifically, there is a 13 case for more investment in low-carbon transport infrastructure than assumed in environmental 14 economics as it induces low-carbon preferences (Creutzig et al. 2016a; Mattauch et al. 2018, 15 2016). Changes in infrastructure provision for active travel may contribute to uptake of more walking 16 and cycling (Frank et al. 2019). These effects contribute to higher uptake of low-carbon travel options, 17 albeit the magnitude of effects depends on design choices and context (Goodman et al. 2013, 2014; 18 Song et al. 2017; Javaid et al. 2020; Abraham et al. 2021). Infrastructure is thus not only required to 19 make low-carbon travel possible but can also be a pre-condition for the formation of low-carbon 20 mobility preferences (also see mobility case study in Box 5.7). | 838 - 838 | 'rot-Adapt-Mitig-Impac | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | Involve arts and humanities to create narratives for policy process Communicate descriptive norms to electricity end users. | 839 - 839 | | | |
| IPCC_AR6_WGIII_Full_Report | 1 2 5.5 An integrative view on transitioning 3 5.5.1 Demand-side transitions as multi-dimensional processes 4 Several integrative frameworks including social practice theory (Røpke 2009; Shove and Walker 2014), 5 the energy cultures framework (Stephenson et al. 2015; Jürisoo et al. 2019) and socio-technical 6 transitions theory (McMeekin and Southerton 2012; Geels et al. 2017) conceptualise demand-side 7 transitions as multi-dimensional and interacting processes (high evidence, high agreement). Social 8 practice theory emphasises interactions between artefacts, competences, and cultural meanings (Røpke 9 2009; Shove and Walker 2014)(Shove and Walker 2014; Røpke 2009). The energy cultures framework 10 highlights feedbacks between materials, norms, and behavioural practices (Stephenson et al. 2015; 11 Jürisoo et al. 2019). Socio-technical transitions theory addresses interactions between technologies, user 12 practices, cultural meanings, business, infrastructures, and public policies (McMeekin and Southerton 13 2012; Geels et al. 2017) and can thus accommodate the five drivers of change and stability discussed in 14 Section 5.4. | 840 - 840 | | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | 15 16 Section 5.4 shows with high evidence and high agreement that the relative influence of different drivers 17 varies between demand-side solutions. The deployment of 'improve' options like LEDs and clean 18 cookstoves mostly involves technological change, adoption by consumers who integrate new 19 technologies in their daily life practices (Smith et al. 1993; Sanderson and Simons 2014; Franceschini 20 and Alkemade 2016), and some policy change. Changes in meanings are less pertinent for those 21 'improve'-options that are primarily about technological substitution. Other improve-options, like clean 22 cookstoves, involve both technological substitution and changes in cultural meanings and traditions. | 840 - 840 | | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 5 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 5-90 Total pages: 192 1 Demand-side transitions involve interactions between radical social or technical innovations (such as 2 the avoid, shift, improve options discussed in Section 5.3) and existing socio-technical systems, energy 3 cultures, and social practices (high evidence, high agreement) (Stephenson et al. 2015; Geels et al. | 840 - 841 | | INTANBILE | |

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| IPCC_AR6_WGIII_Full_Report | 4 2017). Radical innovations such as tele-working, plant-based burgers, car sharing, vegetarianism, or 5 electric vehicles initially emerge in small, peripheral niches (Kemp et al. 1998; Schot and Geels 2008), 6 constituted by R&D projects, technological demonstration projects (Borghei and Magnusson 2016; 7 Rosenbloom et al. 2018b), local community initiatives or grassroots projects by environmental activists 8 (Hargreaves et al. 2013a; Hossain 2016). Such niches offer protection from mainstream selection 9 pressures and nurture the development of radical innovations (Smith and Raven 2012). Many low- 10 carbon niche-innovations, such as those described in Section 5.3, face uphill struggles against existing 11 socio-technical systems, energy cultures, and social practices that are stabilised by multiple lock-in 12 mechanisms (high evidence, high agreement) (Klitkou et al. 2015; Seto et al. 2016; Clausen et al. 2017; 13 Ivanova et al. 2018). Demand-side transitions therefore do not happen easily and involve interacting 14 processes and struggles on the behavioural, socio-cultural, institutional, business and technological 15 dimensions (Nikas et al. 2020) (see also Section 5.4). | 841 - 841 | Prot-Adapt-Mitig- | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | 26 The concept of leapfrogging emerged in development economics (Soete 1985), energy policy 27 (Goldemberg 1991) and environmental regulation (Perkins 2003), which provides a first critical review 28 of the concept), and refers to a development strategy that skips traditional and polluting development ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 5 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 5-94 Total pages: 192 1 in favour of the most advanced concepts. For instance, in rural areas without telephone landlines or 2 electricity access (cables), a direct shift to mobile telephony or distributed, locally-sourced energy 3 systems is promoted, or economic development policies for pre-industrial economies forego the 4 traditional initial emphasis of heavy industry industrialisation, instead of focusing on services like 5 finance or tourism. Often leapfrogging is enabled by learning and innovation externalities where 6 improved knowledge and technologies become available for late adopters at low costs. The literature 7 highlights many cases of successful leapfrogging but also highlights limitations (for a review see 8 Watson and Sauter (Watson and Sauter 2011); with example case studies for China e.g. Gallagher 9 (Gallagher 2006) or Chen and Li-Hua (Chen and Li-Hua 2011); Mexico (Gallagher and Zarsky 2007); 10 or Japan and Korea, e.g. Cho et al. (Cho et al. 1998). Increasingly the concept is being integrated into 11 the literature of low-carbon development, including innovation and technology transfer policies (for a 12 review see Pigato (Pigato et al. 2020)), highlighting in particular the importance of contextual factors 13 of successful technology transfer and leapfrogging including: domestic absorptive capacity and 14 technological capabilities (Cirera and Maloney 2017); human capital, skills, and relevant technical 15 know-how (Nelson and Phelps 1966); the size of the market (Keller 2004); greater openness to trade 16 (Sachs and Warner 1995; Keller 2004); geographical proximity to investors and financing (Comin et 17 al. 2012); environmental regulatory proximity (Dechezleprêtre et al. 2015); and stronger protection 18 of intellectual property rights (Dechezleprêtre et al. 2013; Dussaux et al. 2017). The existence of a 19 technological potential for leapfrogging therefore needs to be considered within a wider context of 20 social, institutional, and economic factors that influence if leapfrogging potentials can be realised (high 21 evidence, high agreement). | 844 - 845 | Prot-Adapt-Mitig- | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | 14 Inclusive and broad-based participation itself also leads to greater social trust and thus is also a key 15 enabler of demand-side climate mitigation (see Section 5.2 for details). Higher social trust and inclusive 16 participatory processes also reduce inequality, restrain opportunistic behaviour and enhance 17 cooperation (Drews and van den Bergh 2016; Gür 2020) (see also Section 5.2). Altogether, broad-based 18 participatory processes are central to the successful implementation of climate policies (Rothstein and 19 Teorell 2008; Klenert et al. 2018) (high evidence , medium agreement). A culture of cooperation feeds 20 back to increase social trust and enables action that reduce GHG emissions (Carattini et al. 2015; Jo and 21 Carattini 2021), and requires including explicit consideration of the informal sector (Box 5.10). More 22 equitable societies also have the institutional flexibility to allow for mitigation to advance faster, given 23 their readiness to adopt locally appropriate mitigation policies; they also suffer less from policy lock-in 24 (Tanner et al. 2009; Lorenz 2013; Chu 2015; Cloutier et al. 2015; Martin 2016; Vandeweerdt et al. | 846 - 846 | Prot-Adapt-Mitig- | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | Use low carbon materials in dwelling design Manufacturing and R&D costs, recycling processes and aesthetic performance (Orsini and Marrone 2019). Access to secondary materials in the building sector (Nußholz et al. | 851 - 851 | | | |

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| IPCC_AR6_WGIII_Full_Report | 39 40 The effectiveness of a policy package is determined by design decisions as well as the wider governance 41 context that include the political environment, institutions for coordination across scales, bureaucratic 42 traditions, and judicial functioning (Howlett and Rayner 2013; Rogge and Reichardt 2013; Rosenow et 43 al. 2016) (high evidence, high agreement). Policy packages often emerge through interactions between 44 different policy instruments as they operate in either complementary or contradictory ways, resulting 45 from conflicting policy goals (Cunningham et al. 2013; Givoni et al. 2013). An example includes the 46 acceleration in shift from traditional biomass to the adoption of modern cooking fuel for 80 million 47 households in rural India over a very short period of 4 years (2016-2020), which employed a 48 comprehensive 'policy package' including financial incentives, infrastructural support and 49 strengthening of the supply chain to induce households to shift towards a clean cooking fuel from the ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 5 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 5-104 Total pages: 192 1 use of biomass (Kumar 2019). This was operationalised by creating a LPG supply chain by linking oil 2 and gas companies with distributors to assure availability, create infrastructure for local storage along 3 with an improvement of the rural road network, especially in the rural context (Sankhyayan and 4 Dasgupta 2019). State governments initiated separate policies to increase the distributorship of LPG in 5 their states (Kumar et al. 2016). Similarly, policy actions for scaling up electric vehicles need to be well 6 designed and coordinated where EV policy, transport policy and climate policy are used together, 7 working on different decision points and different aspects of human behaviour (Barton and Schütte 8 2017). The coordination of the multiple policy actions enables co-evolution of multiple outcomes that 9 involve shifting towards renewable energy production, improving access to charging infrastructure, 10 carbon pricing and other GHG measures (Wolbertus et al. 2018). | 854 - 855 | Impact | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | 4 5 6 5.7 Knowledge gaps 7 Knowledge gap 1: Better metric to measure actual human well-being 8 Knowledge on climate action that starts with the social practices and how people live in various 9 environments, cultures, contexts and attempts to improve their well-being, is still in its infancy. In 10 models, climate solutions remain supply-side oriented, and evaluated against GDP, without 11 acknowledging the reduction in well-being due to climate impacts. GDP is a poor metric of human well- 12 being, and climate policy evaluation requires better grounding in relation to decent living standards and 13 or similar benchmarks. Actual solutions will invariably include demand, service provisioning and end 14 use. Literature on how gender, informal economies mostly in developing countries, and solidarity and 15 care frameworks translate into climate action, but also how climate action can improve the life of 16 marginalised groups remains scarce. The working of economic systems under a well-being driven rather 17 than GDP driven paradigm requires better understanding. | 856 - 856 | Impact | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | 40 Tolerating ambiguity can be learned, e.g., by interacting with history, poetry and the arts. Sometimes 41 religion and philosophy also help. | 857 - 857 | | | |
| IPCC_AR6_WGIII_Full_Report | 42 43 As a key enabler, novel narratives created in a variety of ways e.g., by advertising, images, 44 entertainment industry, help to break away from the established meanings, values and discourses and 45 the status quo. For example, discourses that frame comfortable public transport service to avoid stress 46 from driving cars on busy, congested roads help avoid car driving as a status symbol and create a new 47 social norm to shift to public transport. Discourses that portray plant based protein and as healthy and 48 natural promote and stabilise particular diets. Novel narratives and inclusive processes help strategies 49 to overcome multiple barriers. Case studies demonstrate that citizens support transformative changes if 50 participatory processes enable a design that meets local interests and culture. Promising narratives ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 5 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 5-107 Total pages: 192 1 specify that even as speed and capabilities differ humanity embarks on a joint journey towards well- 2 being for all and a healthy planet. | 857 - 858 | | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | 24 Solar energy elicits favourable public responses in most countries (high confidence) (Bessette and Arvai 25 2018; Hanger et al. 2016; Jobin and Siegrist 2018; Ma et al. 2015; Mcgowan and Sauter 2005; Hazboun 26 and Boudet 2020; Roddis et al. 2019). Solar energy is perceived as clean and environmentally friendly 27 with few downsides (Faiers and Neame 2006; Whitmarsh et al. 2011b). Key motivations for 28 homeowners to adopt photovoltaic systems are expected financial gains, environmental benefits, the 29 desire to become more self-sufficient, and peer expectations (Korcaj et al. 2015; Palm 2017; Vasseur 30 and Kemp 2015). Hence, the observability of photovoltaic systems can facilitate adoption (Boudet 31 2019). The main barriers to the adoption of solar PV by households are its high upfront costs, aesthetics, 32 landlord-tenant incentives, and concerns about performance and reliability (Whitmarsh et al. 2011b; 33 Vasseur and Kemp 2015; Faiers and Neame 2006). | 970 - 970 | | | |

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| IPCC_AR6_WGIII_Full_Report | 16 Wind capacity factors have increased over the last decade (Figure 6.11). The capacity factor for onshore 17 wind farms increased from 27% in 2010 to 36% in 2020 (IRENA 2021a). The global average offshore 18 capacity factor has decreased from a peak of 45% in 2017. This has been driven by the increased share 19 of offshore development in China, where projects are often near-shore and use smaller wind turbines 20 than in Europe (IRENA 2021b). Improvements in capacity factors also come from increased 21 functionality of wind turbines and wind farms. Manufactures can adapt the wind turbine generator to 22 the wind conditions. Turbines for windy sites have smaller generators and smaller specific capacity per 23 rotor area, and therefore operate more efficiently and reach full capacity for a longer time period (Rohrig 24 et al. 2019). | 972 - 972 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGIII_Full_Report | In 2020, typical country-average total installed costs were around USD 1150 kW-1 11 in China and India, and between USD 1403–2472 kW-1 12 elsewhere (IRENA 2021b). Total installed costs of offshore wind 13 farms declined by 12% between 2010 and 2020. But, because some of the new offshore wind projects 14 have moved to deeper waters and further offshore, there are considerable year-to-year variations in their 15 price (IRENA 2021b). Projects outside China in recent years have typically been built in deeper waters 16 (10–55 m) and up to 120 km offshore, compared to around 10 m in 2001–2006, when distances rarely 17 exceeded 20 km. With the shift to deeper waters and sites further from ports, the total installed costs of offshore wind farms rose, from an average of around USD 2500 kW-1 in 2000 to around USD 5127 kW- 18 1 by 2011–2014, before falling to around USD 3185 kW-1 19 in 2020 (IRENA 2020a). The full cost of 20 wind power includes the transmission and system integration costs (Sections 6.4.3, 6.4.6. A new 21 technology in development is the co-location of wind and solar PV power farms, also known as hybrid 22 power plants. Co-locating wind, solar PV, and batteries can lead to synergies in electricity generation, 23 infrastructure, and land usage, which may lower the overall plant cost compared to single technology 24 systems (Lindberg et al. 2021). | 973 - 973 | | | |
| IPCC_AR6_WGIII_Full_Report | 14 Public support for onshore and particularly offshore wind energy is generally high, although people 15 may oppose specific wind farm projects (high confidence) (e.g., Rand and Hoen 2017; Steg 2018; Bell 16 et al. 2005; Batel and Devine-Wright 2015). People generally believe that wind energy is associated 17 with environmental benefits and that it is relatively cheap. Yet, some people believe wind turbines can 18 cause noise and visual aesthetic pollution, threaten places of symbolic value (Russell et al. 2020; 19 Devine-Wright and Wiersma 2020), and have adverse effects on wildlife (Bates and Firestone 2015), 20 which challenges public acceptability (Rand and Hoen 2017). Support for local wind projects is higher 21 when people believe fair decision-making procedures have been implemented (Aitken 2010a; Dietz and 22 Stern 2008). Evidence is mixed whether distance from wind turbines or financial compensation 23 increases public acceptability of wind turbines (Hoen et al. 2019; Rand and Hoen 2017; Cass et al. | 974 - 974 | Impact | | |
| IPCC_AR6_WGIII_Full_Report | 10 Hydropower is one of the lowest-cost electricity technologies (Mukheibir 2013; IRENA 2021b). Its operation and maintenance costs are typically 2–2.5% of the investment costs per kW yr-1 11 for a lifetime 12 of 40–80 years (Killingtveit 2020). Construction costs are site specific. The total cost for an installed large hydropower project varies from USD 10,600–804,500 kW-1 13 if the site is located far away from 14 transmission lines, roads, and infrastructure. Investment costs increase for small hydropower plants and may be as high as USD 100,000 kW-1 15 or more for the installation of plants of less than 1 MW - 20% to 16 80% more than for large hydropower plants (IRENA 2015). During the past 100 years, total installed 17 costs and LCOE have risen by a few percent, but the LCOE of hydropower remains lower than the 18 cheapest new fossil fuel-fired option (IRENA 2019b, 2021). | 976 - 976 | | | |
| IPCC_AR6_WGIII_Full_Report | 43 • Small Modular Reactors. There are more than 70 SMR designs at different stages of consideration 44 and development, from the conceptual phase to licensing and construction of first-of-a-kind 45 facilities (IAEA 2020). Due to smaller unit sizes, the SMRs are expected to have lower total 46 investment costs, although the cost per unit of generation might be higher than conventional large 47 reactors (Mignacca and Locatelli 2020). Modularity and off-site pre-production may allow greater 48 efficiency in construction, shorter delivery times, and overall cost optimization (IEA 2019c). SMR ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 6 IPCC WGIII AR6 Do Not Cite, Quote or Distribute 6-35 Total pages: 217 1 designs aim to offer an increased load-following capability that makes them suitable to operate in 2 smaller systems and in systems with increasing shares of VRE sources. Their market development 3 by the early 2030s will strongly depend on the successful deployment of prototypes during the 4 2020s. | 977 - 978 | | | |

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| IPCC_AR6_WGIII_Full_Report | 33 Additionally, new technologies are being developed like Enhanced Geothermal Systems (EGS), which 34 is in the demonstration stage (IRENA 2018), deep geothermal technology, which may increase the 35 prospects for harnessing the geothermal potential in a large number of countries, or shallow-geothermal 36 energy, which represents a promising supply source for heating and cooling buildings (Narsilio and Aye 37 2018). Successful large-scale deployment of shallow geothermal energy will depend not only on site- 38 specific economic performance but also on developing suitable governance frameworks (Bloemendal ACCEPTED VERSION SUBJECT TO FINAL EDITS Final Government Distribution Chapter 6 IPCC WGIII AR6 Do Not Cite, Quote or Distribute 6-47 Total pages: 217 1 et al. 2018; García-Gil et al. 2020). Technologies for direct uses like district heating, geothermal heat 2 pumps, greenhouses, and other applications are widely used and considered mature. Given the limited 3 number of plants commissioned, economic indicators (Figure 6.15) vary considerably depending on site 4 characteristics. | 989 - 990 | | | |
| IPCC_AR6_WGIII_Full_Report | 19 Hydrogen production processes (power-to-gas and vice versa) and hydrogen storage can support short- 20 term and long-term balancing in the energy systems and enhance resilience (Stephen and Pierluigi 2016; 21 Strbac et al. 2020). However, the economic benefits of flexible power-to-gas plants, energy storage, 22 and other flexibility technological and options will depend on the locations of VRE sources, storage 23 sites, gas, hydrogen, and electricity networks (Jentsch et al. 2014; Heymann and Bessa 2015; Ameli et 24 al. 2020). Coordinated operation of gas and electricity systems can bring significant benefits in 25 supplying heat demands. For example, hybrid heating can eliminate investment in electricity 26 infrastructure reinforcement by switching to heat pumps in off-peak hours and gas boilers in peak hours 27 ( Dengiz et al. 2019; Fischer et al. 2017; Bistline et al. 2021). The heat required by direct air carbon 28 capture and storage (DACCS) could be effectively supplied by inherent heat energy in nuclear plants, 29 enhancing overall system efficiency (Realmonte et al. 2019). | 992 - 992 | Impact | | |
| IPCC_AR6_WGIII_Full_Report | 5 2014). New possibilities are being explored for small-scale PHS installations and expanding the 6 potential for siting (Kougias et al. 2019). For example, in underwater PHS, the upper reservoir is the 7 sea, and the lower is a hollow deposit at the seabed. Seawater is pumped out of the deposit to store off- 8 peak energy and re-enters through turbines to recharge it (Kougias et al. 2019). Using a similar concept, 9 underground siting in abandoned mines and caverns could be developed reasonably quickly (IEA 10 2020h). Storage of energy as gravitational potential can also be implemented using materials other than 11 water, such as rocks and sand. Pumped technology is a mature technology (Barbour et al. 2016; Rehman 12 et al. 2015) and can be important in supporting the transition to future low carbon electricity grids (IHA 13 2021). | 997 - 997 | | | |
| IPCC_AR6_WGIII_Full_Report | 26 27 Table 6.6 Technical characteristics of a selected range of battery chemistries, categorized as those which 28 precede LIBs (white background), LIBs (yellow background) and post LIBs (blue background). With the 29 exception of the All Solid-State batteries, all use liquid electrolytes. (1 =Mahmoudzadeh et al. 2017; 2 = 30 Manzetti and Mariasiu 2015; 3 =Placke et al. 2017; 4 = Nykvist and Nilsson 2015; 5 =Cano et al. 2018; 6 = 31 BloombergENF 2019; 7 = You and Manthiram 2017; 8 = Fotouhi et al. 2017; 9 = IRENA 2017; 10 = Yang 32 et al., 2020) Battery Type Technology Maturity Life Span (Cycles) Energy Density (Wh L-1 ) Specific Energy (Wh kg-1 ) Price (USD kWh-1 ) in 2017 Lead Acid High 300–800 5 102–106 5 38–60 5 70–160 5 Ni MH High 600–1200 5 220–250 5 42–110 5 210–365 5 Ni Cd High 1350 2 100 2 60 2 700 High-temperature Na batteries High 1000 5 150–280 8 80–120 1 315–490 8 LIB state of the art High 1000–6000 5 200–680 3 110–250 3 176 6 LIB energy-optimized Under Development 600–850 3 300-440 3 Classic Li Metal (CLIM) Under Development 800–1050 3 420–530 3 Metal Sulfur (Li S) Near Commercialization 100–500 5 350–680 3, 8 360–560 3, 8 36–130 5 Metal Sulfur (Na S) Under Development 5000–10,000 8 Metal Air (Li/air) Under Development 20–100 5 470–900 4 70–200 5 ACCEPTED VERSION SUBJECT TO FINAL EDITS Final Government Distribution Chapter 6 IPCC WGIII AR6 Do Not Cite, Quote or Distribute 6-55 Total pages: 217 Metal Air (Zn/air) Under Development 150–450 5 200–410 4 70–160 5 Na ion Under Development 500 7 600 7 All-Solid-State Under Development 278–479 3 Redox Under Development >12,000– 14,000 10 15–2510 10–2010 6610 1 2 Drawbacks of batteries include relatively short lifespans and the use of hazardous or costly materials in 3 some variants. While LIB costs are decreasing (Schmidt et al. 2017; Vartiainen et al. 2020), the risk of 4 thermal runaway, which could ignite a fire (Gur 2018; Wang et al. 2019a), concerns about long-term 5 resource availability (Sun et al. 2017; Olivetti et al. 2017), and concerns about global cradle-to-grave 6 impacts (Peters et al. 2017; Kallitsis et al. 2020) need to be addressed. | 997 - 998 | Impact | | |

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| IPCC_AR6_WGIII_Full_Report | 7 Bulk Hydrogen Storage. Currently, hydrogen is stored in bulk in chemical processes such as metal and 8 chemical hydrides as well as in geologic caverns (Andersson and Grönkvist 2019; Caglayan et al. 2019) 9 (e.g., salt caverns operate in Sweden) (Elberry et al. 2021). There are still many challenges, however, 10 due to salt or hard rock geologies, large size, and minimum pressure requirements of the sites (IEA 11 2019c). Consequently, alternative carbon-free energy carriers, which store hydrogen, may become more 12 attractive (Kobayashi et al. 2019; Lan et al. 2012). | 1005 - 1005 | | | |
| IPCC_AR6_WGIII_Full_Report | 5 Other technologies that could expand the size of transmission corridors and/or improve the operational 6 characteristics include low-frequency AC transmission (LFAC) (Xiang et al. 2021; Tang et al. 2021b) 7 and half-wave AC transmission (HWACT) (Song et al. 2018; Xu et al. 2019). LFAC is technically 8 feasible, but the circumstances in which it is the best economic choice compared to HVDC or HVAC 9 still needs to be established (Xiang et al. 2016). HWACT is restricted to very long distances, and it has 10 not been demonstrated in practice, so its feasibility is unproven. There are still a number of 11 technological challenges for long-distance transmission networks such as protection systems for DC or 12 hybrid AC-DC networks (Franck C. et al. 2017; Chaffey 2016), improvement in cabling technology, 13 and including the use of superconductors and nanocomposites (Ballarino et al. 2016; Doukas 2019), 14 which require advanced solutions. | 1006 - 100( | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGIII_Full_Report | 21 Contextual factors, such as physical and climate conditions, infrastructure, available technology, 22 regulations, institutions, culture, and financial conditions define the costs and benefits of mitigation 23 options that enable or inhibit their adoption (high confidence). Geographic location and climate factors 24 may make some technologies, such as solar PV or solar water heaters, impractical (Chang et al. 2009). | 1007 - 100( | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGIII_Full_Report | 25 Culture can inhibit efficient use of home heating or PV (Sovacool and Griffiths 2020), low carbon diets 26 (Dubois et al. 2019), and advanced fuel choices (Van Der Kroon et al. 2013). Also, favourable financial 27 conditions promote the uptake of PV (Wolske and Stern 2018), good facilities increase recycling 28 (Geiger et al. 2019), and vegetarian meal sales increase when more vegetarian options are offered.. | 1007 - 1007 | | | |
| IPCC_AR6_WGIII_Full_Report | Baseline New coal Existing coal New NGCC Existing NGCC Baseline emissions rate (tonCO2 MWh- 1 ) 0.8 0.9 0.34 0.42 LCOE (USD2020 kWh-1 ) 0.065 0.041 0.044 0.028 Utility scale solar PV (poor resource site) 0.100 44 USD tCO2- eq-1 66 USD tCO2- eq-1 165 USD tCO2- eq-1 171 USD tCO2- eq-1 Utility scale solar PV (good resource site) 0.035 –38 USD tCO2- eq-1 –7 USD tCO2- eq-1 –26 USD tCO2- eq-1 17 USD tCO2- eq-1 9 10 The feasibility and desirability of mitigation options extends well beyond the market economic costs of 11 installation and operation (Section 6.4.1). Figure 6.19 summarizes the barriers and enablers for 12 implementing different mitigation options in energy systems. The feasibility of different options can be 13 enhanced by removing barriers and/or strengthening enablers of the implementation of the options. The 14 feasibility of options may differ across context (e.g., region), time (e.g., 2030 versus 2050), scale (e.g., 15 small versus large) and the long-term warming goal (e.g., 1.5°C versus 2°C). | 1010 - 101 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGIII_Full_Report | 15 ● Culture can encompass the articulation of positive discourses, narratives, and visions that enhance 16 cultural legitimacy and societal acceptance of new technologies. Regulatory embedding can capture 17 the variety of policies that shape production, markets and use of new technologies. | 1056 - 1056 | | INTANBILE | |

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| IPCC_AR6_WGII_Full_Report | 26 7.3.1.5. Logging and fuelwood harvest 27 The area of forest designated for production has been relatively stable since 1990. Considering forest 28 uses, about 30% (1.2 billion ha) of all forests is used primarily for production (wood and non-wood 29 forest products), about 10% (424 Mha) is designated for biodiversity conservation, 398 Mha for the 30 protection of soil and water, and 186 Mha is allocated for social services (recreation, tourism, education 31 research and the conservation of cultural and spiritual sites) (FAO and UNEP 2020). While the rate of 32 increase in the area of forest allocated primarily for biodiversity conservation has slowed in the last ten 33 years, the rate of increase in the area of forest allocated for soil and water protection has grown since 34 1990, and notably in the last ten years. Global wood harvest (including from forests, other wooded land and trees outside forests) was estimated to be almost 4.0 billion m3 35 in 2018 (considering both industrial 36 roundwood and fuelwood) (FAO, 2019). Overall, wood removals are increasing globally as demand 37 for, and the consumption of wood products grows annually by 1% in line with growing populations and 38 incomes with this trend expected to continue in coming decades. When done in a sustainable way, more 39 regrowth will occur and is stimulated by management, resulting in a net sink. However illegal and 40 unsustainable logging (i.e. harvesting of timber in contravention of the laws and regulations of the 41 country of harvest) is a global problem with significant negative economic (e.g. lost revenue), 42 environmental (e.g. deforestation, forest degradation, GHG emissions and biodiversity losses) and 43 social impact (e.g. conflicts over land and resources, disempowerment of local and indigenous 44 communities) (World Bank 2019). Many countries around the world have introduced regulations for 45 the international trade of forest products to reduce illegal logging, with significant and positive impacts 46 (Guan et al. 2018). | 1193 - 119 | 'rot-Adapt-Mitig-Impa | INTANBILE | INDG |
| IPCC_AR6_WGII_Full_Report | Science and technology Technological factors operates in conjunction with economic drivers of land use and management, whether through intensified farming techniques and biotechnology, high-input approaches to rehabilitating degraded land (e.g. Lin et al. 2017; Guo et al. 2020) or through new forms of data collection and monitoring (e.g. Song et al. 2018; Thyagharajan and Vignesh 2019; Arévalo et al. 2020). | 1197 - 1197 | | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | Research and development are central to forest restoration strategies that have become increasingly important around the world as costs vary depending on methods used, from natural regeneration with native tree species to active restoration using site preparation and planting (Löf et al. 2019). | 1197 - 1197 | | | |
| IPCC_AR6_WGII_Full_Report | 5 Key uncertainties remain in mapping extent and conversion rates for salt marshes and seagrasses (McKenzie et al. 2020). Seagrass loss rates were estimated at 1-2% y-1 6 (Dunic et al. 2021) with 7 stabilization in some regions (IPCC WGII Ch. 3.4.2.5; (de los Santos et al. 2019); however, loss occurs 8 non-linearly and depends on site-specific context. Tidal marsh extent and conversion rates remains 9 poorly estimated, outside of the USA, Europe, South Africa, and Australia (Mcowen et al. 2017; 10 Macreadie et al. 2019). | 1220 - 1220 | | | |
| IPCC_AR6_WGII_Full_Report | 18 7.4.2.9. Coastal wetland restoration 19 Activities, co-benefits, risks and implementation barriers. Coastal wetland restoration involves 20 restoring degraded or damaged coastal wetlands including mangroves, salt marshes, and seagrass 21 ecosystems, leading to sequestration of 'blue carbon' in wetland vegetation and soil (SRCCL Ch 6, 22 SROCCC Ch 5). Successful approaches to wetland restoration include: (1) passive restoration, the 23 removal of anthropogenic activities that are causing degradation or preventing recovery; and (2) active 24 restoration, purposeful manipulations to the environment in order to achieve recovery to a naturally 25 functioning system (Elliott et al. 2016; IPCC WGII Ch 3). Restoration of coastal wetlands delivers 26 many valuable co-benefits, including enhanced water quality, biodiversity, aesthetic values, fisheries 27 production (food security), and protection from rising sea levels and storm impacts (Barbier et al. 2011; Hochard et al. 2019; Sun and Carson 2020; Duarte et al. 2020). Of the 0.3 Mkm2 28 coastal wetlands globally, 0.11 Mkm2 29 of mangroves are considered feasible for restoration (Griscom et al. 2017). Risks 30 associated with coastal wetland restoration include uncertain permanence under future climate scenarios 31 (IPCC WGII AR6 Box 3.4), partial offsets of mitigation through enhanced methane and nitrous oxide 32 release and carbonate formation, and competition with other land uses, including aquaculture and 33 human settlement and development in the coastal zone (SROCCC, Chapter 5). To date, many coastal 34 wetland restoration efforts do not succeed due to failure to address the drivers of degradation (van 35 Katwijk et al. 2016). However, improved frameworks for implementing and assessing coastal wetland 36 restoration are emerging that emphasize the recovery of ecosystem functions (Cadier et al. 2020; Zhao 37 et al. 2016). Restoration projects that involve local communities at all stages and consider both 38 biophysical and socio-political context are more likely to succeed (Brown et al. 2014; Wylie et al. 2016). | 1220 - 122 | 'rot-Adapt-Mitig-Impa | | |

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| IPCC_AR6_WGIII_Full_Report | 27 There is high site-specific variation in carbon sequestration rates and uncertainties regarding the 28 response to future climate change (Jennerjahn et al. 2017; Nowicki et al. 2017; IPCC WGII AR6 Box 29 3.4). Changes in distributions (Kelleway et al. 2017; Wilson and Lotze 2019), methane release (Al-Haj 30 and Fulweiler 2020), carbonate formation (Saderne et al. 2019), and ecosystem responses to interactive 31 climate stressors are not well-understood (Short et al. 2016; Fitzgerald and Hughes 2019; Lovelock and 32 Reef 2020). | 1221 - 1221 | | | |
| IPCC_AR6_WGIII_Full_Report | 23 2016). Besides CDR, additional mitigation can arise from displacing fossil fuels with pyrolysis gases, 24 lower soil N2O emissions (Cayuela et al. 2014, 2015; Song et al. 2016; He et al. 2017; Verhoeven et al. | 1223 - 122 | Prot-Adapt-Mitig- | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | 25 2017; Borchard et al. 2019), reduced nitrogen fertiliser requirements due to reduced nitrogen leaching 26 and volatilisation from soils (Liu et al. 2019; Borchard et al. 2019), and reduced GHG emissions from 27 compost when biochar is added (Agyarko-Mintah et al. 2017; Wu et al. 2017). Biochar application to 28 paddy rice has resulted in substantial reductions (20-40% on average) in N2O (Awad et al. 2018; Liu et 29 al. 2018; Song et al. 2016) (Section 7.4.3.5) and smaller reduction in CH4 emissions (Kammann et al. | 1223 - 1223 | | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | 30 2017; Kim et al. 2017a; Song et al. 2016; He et al. 2017; Awad et al. 2018). Potential co-benefits include 31 yield increases particularly in sandy and acidic soils with low cation exchange capacity (Woolf et al. | 1223 - 1223 | | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | 7 2018; Gao et al. 2020) and reduced GHG and ammonia emissions from compost and manure (Sanchez- 8 Monedero et al. 2018; Bora et al. 2020a,b; Zhao et al. 2020). A quantification method based on biochar 9 properties is included in the IPCC guidelines for NGHGIs (IPCC 2019b). Studies report a range of 10 biochar responses, from positive to occasionally adverse impacts, including on GHG emissions, and 11 identify risks (Tisserant and Cherubini 2019). This illustrates the expected variability (Lehmann and 12 Rillig 2014) of responses, which depend on the biochar type and climatic and edaphic characteristics of 13 the site (Zygourakis 2017). Biochar properties vary with feedstock, production conditions and post- 14 production treatments, so mitigation and agronomic benefits are maximised when biochars are chosen 15 to suit the application context (Mašek et al. 2018). A recent assessment finds greatest economic potential (up to USD100 tCO2 -1 16 ) between 2020 and 2050 to be in Asia and the developing Pacific (793 MtCO2 yr-1 ) followed by Developed Countries (447 MtCO2 yr-1 17 ) (Roe et al. 2021). Mitigation through biochar 18 will be greatest where biochar is applied to responsive soils (acidic, low fertility), where soil N2O 19 emissions are high (intensive horticulture, irrigated crops), and where the syngas co-product displaces 20 fossil fuels. Due to the early stage of commercialisation, mitigation estimates are based pilot-scale 21 facilities, leading to uncertainty. However, the long-term persistence of biochar carbon in soils has been 22 widely studied (e.g. Singh et al. 2012; Fang et al. 2019; Zimmerman and Ouyang 2019). The greatest 23 uncertainty is the availability of sustainably-sourced biomass for biochar production. | 1224 - 122 | 'rot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGIII_Full_Report | 42 Barriers to adoption may include site-specific limitations regarding soil type, percolation and seepage 43 rates or fluctuations in precipitation, water canal or irrigation infrastructure, paddy surface level and 44 rice field size, and social factors including farmer perceptions, pump ownership, and challenges in 45 synchronising water management between neighbours and pumping stations (Yamaguchi et al. 2019; 46 Yamaguchi et al. 2017; Quynh and Sander 2015). | 1228 - 1228 | | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | 9 Developments since AR5 and IPCC Special Reports (SR1.5, SROCCC and SRCCL). Since AR5 and 10 the SRCCL, studies on mitigation have principally focused on water and nutrient management practices 11 with the aim of improving overall sustainability as well as measurements of site-specific emissions to 12 help improve the resolution of regional estimates. Intensity of emissions show considerable spatial and 13 temporal variation, dependent on site specific factors including degradation of soil organic matter, 14 management of water levels in the field, the types and amount of fertilisers applied, rice variety and local cultivation practices. Variation in CH4 emissions have been found to range from 0.5-41.8 mg/m2 15 /hr 16 in Southeast Asia (Sander et al. 2014; Chidthaisong et al. 2018; Setyanto et al. 2018; Sibayan et al. | 1229 - 122 | Prot-Adapt-Mitig- | | |

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| IPCC_AR6_WGIII_Full_Report | 27 2018). Water management for both single and multiple drainage can (most likely) reduce methane 28 emissions by ~35 % but increase N2O emissions by about 20% (Yagi et al. 2020). However, N2O 29 emissions occur only under dry conditions, therefore total reduction in terms of net GWP is 30 approximately 30%. Emissions of N2O are higher during dry seasons (Yagi et al. 2020) and depend on 31 site specific factors as well as the quantity of fertiliser and organic matter inputs into the paddy rice 32 system. Variability of N2O emissions from single and multiple drainage can range from 0.06-33 kg/ha 33 (Hussain et al. 2015; Kritee et al. 2018). AWD in Vietnam was found to reduce both CH4 and N2O 34 emissions by 29-30 and 26-27% respectively with the combination of net GWP about 30% as compared 35 to continuous flooding (Tran et al. 2018). Overall, greatest average economic mitigation potential (up to USD100 tCO2-eq-1 36 ) between 2020 and 2050 is estimated to be in Asia and the developing Pacific (147.2 MtCO2-eq yr-1 ) followed by Latin America and the Caribbean (8.9 MtCO2-eq yr-1 37 ) using the 38 IPCC AR4 GWP100 value for CH4 (Roe et al. 2021). | 1229 - 122 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGIII_Full_Report | 39 Critical assessment and conclusion. There is medium confidence that improved rice management has a technical potential of 0.3 (0.1-0.8) GtCO2-eq yr-1 40 between 2020 and 2050, of which 0.2 (0.05-0.3) GtCO2-eq yr-1 is available up to USD100 tCO2-eq-1 41 (Figure 7.11). Improving rice cultivation practices 42 will not only reduce GHG emissions, but also improve production sustainability in terms of resource 43 utilisation including water consumption and fertiliser application. However, emission reductions show 44 high variability and are dependent on site specific conditions and cultivation practices. | 1229 - 1229 | | | |
| IPCC_AR6_WGIII_Full_Report | 33 Interactions and limitations 34 The integration of technologies and services that are suitable for the local conditions resulted in many 35 gains for food security and adaptation and for mitigation where appropriate. It was also shown that, in 36 all regions, there is considerable yield advantage when a portfolio of technologies is used, rather than 37 the isolated use of technologies (Govaerts et al. 2005; Zougmoré et al. 2014). Moreover, farmers are 38 using research results to promote their products as climate-smart leading to increases in their income 39 (Acosta-Alba et al. 2019). However, climatic risk sites and socioeconomic conditions together with a 40 lack of resource availability are key issues constraining agriculture across all five regions. | 1231 - 123 | 'rot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGIII_Full_Report | 25 While expectations that carbon-centred REDD+ would be a simple and efficient mechanism for climate 26 mitigation have not been met (Turnhout et al. 2017; Arts et al. 2019), progress has nonetheless occurred. | 1260 - 126 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGIII_Full_Report | 24 Identified lessons - The elements of sustainability are intertwined with Menominee history, culture, 25 spirituality, and ethics. The balance between the environment, community, and economy for the short 26 term as well as future generations is an example of protecting the entire environment as the Menominee 27 land is a non-fragmented remnant of the prehistoric Lake States forest which has been dramatically 28 reduced all around the reserve (Schabel and Pecore 1997). These and other types of community forest 29 owner associations exist all over the world. Examples are Södra in Sweden (with 52,000 forest owners) 30 (Södra, 2021) or Waldbauernverband in North-Rhine Westphalia (with 150,000 forest owners and 31 covering 585,000 ha) (AGDW-The Forest Owners, 2021). These are ways for small forest owners 32 to educate, jointly put wood on the market, employ better forest management, use machinery together, 33 and apply certification jointly. In this manner and with all their diversity of goals, they manage to 34 maintain carbon sinks and stocks, while preserving biodiversity and producing wood. | 1263 - 126 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGIII_Full_Report | 42 Permanence focuses on the potential for carbon sequestered in offsets to be released in the future due 43 to natural or anthropogenic disturbances. Most offset registries have strong permanence requirements, 44 although they vary in their specific requirements. VCS/Verra requires a pool of additional carbon credits 45 that provides a buffer against inadvertent losses. The Climate Action Reserve (CAR) protocol for forests ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 7 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 7-108 Total pages: 185 1 requires carbon to remain on the site for 100 years. The carbon on the site will be verified at pre- 2 determined intervals over the life of the project. If carbon is diminished on a given site, the credits for 3 the site have to be relinquished and the project developer has to use credits from their reserve fund 4 (either other projects or purchased credits) to make up for the loss. Estimates of leakage in forestry 5 projects in the AR5 suggest that it can range from 10% to over 90% in the USA (Murray et al. 2004), 6 and 20-50% in the tropics (Sohngen and Brown 2004) for forest set-asides and reduced harvesting. | 1267 - 1268 | | | |

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| IPCC_AR6_WGIII_Full_Report | 7 Financing needs in AFOLU, and in particular in forestry, include both the direct effects of any changes 8 in activities – costs of planting or managing trees, net revenues from harvesting, costs of thinning, costs 9 of fire management, etc. – as well as the opportunity costs associated with land use change. Opportunity 10 costs are a critical component of AFOLU finance, and must be included in any estimate of the funds 11 necessary to carry out projects. They are largest, as share of total costs, in forestry because they play a 12 prominent role in achieving high levels of afforestation, avoided deforestation, and improved forest 13 management. In case of increasing soil carbon in croplands through reduced tillage, there are often cost 14 savings associated with increased residues because there is less effort tilling, but the carbon effects per 15 hectare are also modest. There could, however, be small opportunity costs in cases where residues may 16 otherwise be marketed to a biorefinery. The effect of reduced tillage on yields varies considerably across 17 sites and crop types, but tends to enhance yields modestly in the longer-run. | 1273 - 127 | Impact | | |
| IPCC_AR6_WGIII_Full_Report | 37 Cultural values and social acceptance. Barriers to adoption of AFOLU mitigation will be strongest 38 where historical practices represent long-standing traditions (high confidence). Adoption of new 39 mitigation practices, however, may proceed quickly if the technologies can be shown to improve crop 40 yields, reduce costs, or otherwise improve livelihoods (Ranjan 2019). AR6 presents new estimates of 41 the mitigation potential for shifts in diets and reductions in food waste, but given long-standing dietary 42 traditions within most cultures, some of the strongest barriers exist for efforts to change diets (medium 43 confidence). Furthermore, the large number of undernourished who may benefit from increased calories 44 and meat will complicate efforts to change diets. Regulatory or tax approaches will face strong 45 resistance, while efforts to use educational approaches and voluntary measures have limited potential 46 to slow changes in consumption patterns due to free-riders, rebound effects, and other limitations. Food ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 7 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 7-114 Total pages: 185 1 loss and waste occurs across the supply chain, creating significant challenges to reduce it (FAO 2019c). | 1273 - 127 | 'rot-Adapt-Mitig-Impa | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | 9 Implementation of nature-based solution may have local or regionally important consequences for other 10 ecosystem services, some of which may be negative (high confidence). Land use change has important 11 implications for the hydrological cycle, and the large land use shifts suggested for BECCS when not 12 carried out in a carefully planned manner, are expected to increase water demands substantially across 13 the globe (Stenzel et al. 2019; Rosa et al. 2020). Afforestation can have minor to severe consequences 14 for surface water acidification, depending on site-specific factors and exposure to air pollution and sea- 15 salts (Futter et al. 2019). The potential effects of coastal afforestation on sea-salt related acidification 16 could lead to re-acidification and damage on aquatic biota. | 1275 - 127 | Impact | | |
| IPCC_AR6_WGIII_Full_Report | 17 Specific soil conditions, water availability, GHG emission-reduction potential as well as natural 18 variability and resilience. Recent analysis by (Cook-Patton et al. 2020) illustrates large variability in 19 potential rates of carbon accumulation for afforestation and reforestation options, both within 20 biomes/ecozones and across them. Their results suggest that while there is large potential for 21 afforestation and reforestation, the carbon uptake potential in land-based climate change mitigation 22 efforts is highly dependent on the assumptions related to climate drivers, land use and land management, 23 and soil carbon responses to land-use change. Less analysis has been conducted on bioenergy crop 24 yields, however, bioenergy crop yields are also likely to be highly variable, suggesting that bioenergy 25 supply could exceed or fall short of expectations in a given region, depending on site conditions. | 1275 - 127 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGIII_Full_Report | 22 7.6.4.4. Technological barriers and opportunities 23 Monitoring, reporting, and verification. Development of satellite technologies to assess potential 24 deforestation has grown in recent years with the release of 30 m data by Hansen et al. (2013), however, 25 this data only captures tree cover loss, and increasing accuracy over time may limit its use for trend 26 analysis (Ceccherini et al. 2020; Palahí et al. 2021). Datasets on forest losses are less well developed 27 for reforestation and afforestation. As Mitchell et al. (2017) point out, there has been significant 28 improvement in the ability to measure changes in tree and carbon density on sites using satellite data, 29 but these techniques are still evolving and improving and they are not yet available for widespread use. | 1276 - 1276 | | | |

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| IPCC_AR6_WGIII_Full_Report | 36 Although numerous studies have estimated the value of ecosystem services for different sites, 37 ecosystems, and regions, these studies mostly evaluate ecosystem services at a single point in time See 38 (Costanza et al. 1997; Nahuelhual et al. 2007; de Groot et al. 2012; Ninan and Kontoleon 2016; Xue 39 and Tisdell 2001). The few studies that have assessed the trends in the value of ecosystem services 40 provided by different ecosystems across regions and countries indicate a declining trend (Costanza et 41 al. 2014; Kubiszewski et al. 2017). Land use change is a major driver behind loss of biodiversity and 42 ecosystem services in most regions (Archer et al. 2018; Rice et al. 2018; IPBES 2018b; M. Fischer et 43 al. 2018). Projected impacts of land use change and climate change on biodiversity and ecosystem 44 services (material and regulating services) between 2015 to 2050 were assessed to have relatively less 45 negative impacts under global sustainability scenarios as compared to regional competition and 46 economic optimism scenarios (Díaz et al. 2019). The projected impacts were based on a subset of 47 Shared Socioeconomic Pathway (SSP) scenarios and GHG emissions trajectories (RCP) developed in ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 7 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 7-119 Total pages: 185 1 support of IPCC assessments. There are synergies, trade-offs and co-benefits between ecosystem 2 services and mitigation options with impacts on ecosystem services differing by scale and contexts 3 (high confidence). Measures such as conservation agriculture, agroforestry, soil and water conservation, 4 afforestation, adoption of silvopastoral systems, can help minimise trade-offs between mitigations 5 options and ecosystem services (Duguma et al. 2014). Climate smart agriculture (CSA) is being 6 promoted to enable farmers to make agriculture more sustainable and adapt to climate change (Box 7 7.4). However, experience with CSA in Africa has not been encouraging. For instance, a study of 8 climate smart cocoa production in Ghana shows that due to lack of tenure (tree) rights, bureaucratic and 9 legal hurdles in registering trees in cocoa farms, and other barriers small cocoa producers could not 10 realise the project benefits (Box 7.13). Experience of CSA in some other Sub-Saharan African countries 11 and other countries such as Belize too has been constrained by weak extension systems and policy 12 implementation, and other barriers (Arakelyan et al. 2017; Kongsager 2017). | 1278 - 127 | Prot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGIII_Full_Report | 40 While appearing to create a net removal of carbon from the atmosphere, BECCS requires land, water 41 and energy which can create adverse side-effects at scale. Controversy has arisen because some of the 42 models calculating the energy mix required to keep the temperature to 1.5°C have included BECCS at 43 very large scales as a means of both providing energy and removing carbon from the atmosphere to 44 offset emissions from industry, power, transport or heat. For example, studies have calculated that for 45 BECCS to achieve 11.5 GtCO2-eq per year of carbon removal in 2100, as envisaged in one scenario, 46 380-700 Mha or 25-46% of all the world's arable and cropland would be needed. In such a situation, ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 7 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 7-124 Total pages: 185 1 competition for agricultural land seriously threatens food production and food security, while also 2 impacting biodiversity, water and soil quality, and landscape aesthetic value. More recently however, 3 the scenarios for BECCS have become much more realistic, though concerns regarding impacts on food 4 security and the environment remain, while the reliability of models is uncertain due to methodological 5 flaws. Improvements to models are required to better capture wider environmental and social impacts 6 of BECCS in order to ascertain its sustainable contribution in emissions pathways. Additionally, the 7 opportunity for other options that could negate very large-scale deployment of BECCS, such as other 8 carbon dioxide removal measures or more stringent emission reductions in other sectors, could be 9 explored within models. | 1283 - 128 | Impact | | |
| IPCC_AR6_WGIII_Full_Report | 7 These mitigation potentials depend on numerous factors and the scale of implementation. The 8 temperature reduction potential for green roofs when compared to conventional roofs can be about 4°C 9 in winter and about 12°C during summer conditions (Bevilacqua et al. 2016). Green roofs can reduce 10 building heating demands by about 10–30% compared to conventional roofs (Besir and Cuce 2018), 11 60–70% compared to black roofs, and 45–60% compared to white roofs (Silva et al. 2016). Green walls 12 or facades can provide a temperature difference between air temperature outside and behind a green 13 wall of up to 10°C, with an average difference of 5°C in Mediterranean contexts in Europe (Perini et 14 al. 2017). The potential of saving energy for air conditioning by green facades can be around 26% in 15 summer months. Considerations of the spatial context are essential given their dependence on climatic 16 conditions (Susca 2019). Cities are diverse and emissions savings potentials depend on several factors, 17 while the implementation of green roofs or facades may be prevented in heritage structures. | 1415 - 141 | Prot-Adapt-Mitig- | | |

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| IPCC_AR6_WGIII_Full_Report | 11 Cities where urban infrastructure has already been built have opportunities to increase energy efficiency 12 measures, prioritize compact and mixed-use neighbourhoods through urban regeneration, advance the 13 urban energy system through electrification, undertake cross-sector synergies, integrate urban green and 14 blue infrastructure, encourage behavioural and lifestyle change to reinforce climate mitigation, and put 15 into place a wide range of enabling conditions as necessary to guide and coordinate actions in the urban 16 system and its impacts in the global system. Retrofitting buildings with state of the art deep energy 17 retrofit measures could reduce emissions of the existing stock by about 30–60% (Creutzig et al. 2016a) 18 and in some cases up to 80% (Ürge-Vorsatz et al. 2020) (see Section 8.4.3). | 1434 - 143 | 'rot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGIII_Full_Report | 48 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 9 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 9-7 Total pages: 168 1 9.1 Introduction 2 Total GHG emissions in the building sector reached 12 GtCO2eq. in 2019, equivalent to 21% of global 3 GHG emissions that year, of which 57% were indirect CO2 emissions from offsite generation of 4 electricity and heat, followed by 24% of direct CO2 emissions produced on-site and 18% from the 5 production of cement and steel used for construction and/or refurbishment of buildings. If only CO2 6 emissions would be considered, the share of buildings CO2 emissions increases to 31% out of global 7 CO2 emissions. Energy use in residential and non-residential buildings contributed 50% and 32% 8 respectfully, while embodied emissions contributed 18% to global building CO2 emissions. Global final 9 energy demand from buildings reached 128.8 EJ in 2019, equivalent to 31% of global final energy 10 demand. Residential buildings consumed 70% out of global final energy demand from buildings. | 1508 - 1509 | | | |
| IPCC_AR6_WGIII_Full_Report | 11 Non-residential buildings have a much broader use. They include cultural buildings (which include 12 theatres and performance, museums and exhibits, libraries, and cultural centres), educational buildings 13 (kindergarten, schools, higher education, research centre, and laboratories), sports (recreation and 14 training, and stadiums), healthcare buildings (health, wellbeing, and veterinary), hospitality (hotel, 15 casino, lodging, nightlife buildings, and restaurants and bars), commercial buildings and offices 16 (institutional buildings, markets, office buildings, retail, and shopping centres), public buildings 17 (government buildings, security, and military buildings), religious buildings (including worship and 18 burial buildings), and industrial buildings (factories, energy plants, warehouses, data centres, 19 transportation buildings, and agricultural buildings). | 1513 - 1513 | | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 9 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 9-12 Total pages: 168 1 2 Figure 9.1 The main building components 3 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 9 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 9-13 Total pages: 168 1 At a global level, from historical perspective (from the Neolithic to the present), building techniques 2 have evolved to be able to solve increasingly complex problems. Vernacular architecture has evolved 3 over many years to address problems inherent in housing. Through a process of trial and error, 4 populations have found ways to cope with the extremes of the weather. The industrial revolution was 5 the single most important development in human history over the past three centuries. Previously, 6 building materials were restricted to a few manmade materials (lime mortar and concrete) along with 7 those available in nature as timber and stone. Metals were not available in sufficient quantity or 8 consistent quality to be used as anything more than ornamentation. The structure was limited by the 9 capabilities of natural materials; this construction method is called on-site construction which all the 10 work is done sequentially at the buildings site. The Industrial Revolution changed this situation 11 dramatically, new building materials emerged (cast-iron, glass structures, steel-reinforced concrete, 12 steel). Iron, steel and concrete were the most important materials of the nineteenth century (De 13 Villanueva Domínguez 2005; Wright 2000). In that context, prefabricated buildings (prefabrication also 14 known as pre-assembly or modularization) appeared within the so-called off-site construction. | 1513 - 1515 | | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGIII_Full_Report | 15 Prefabrication has come to mean a method of construction whereby building elements and materials, 16 ranging in size from a single component to a complete building, are manufactured at a distance from 17 the final building location. Prefabricated buildings have been developed rapidly since World War II and 18 are widely used all over the world (Pons 2014; Moradibistouni et al. 2018) 19 Recently, advances in technology have produced new expectations in terms of design possibilities. In 20 that context, 3D printing seems to have arrived. 3D printing may allow in the future to build faster, 21 cheaper and more sustainable (Agustí-Juan et al. 2017; García de Soto et al. 2018). At the same time, it 22 might introduce new aesthetics, new materials, and complex shapes that will be printed at the click of 23 a mouse on our computers. Although 3D printing will not replace architectural construction, it would 24 allow optimization of various production and assembly processes by introducing new sustainable 25 construction processes and tools (De Schutter et al. 2018). Nevertheless, what is clear is that 3D printing 26 is a technology still in development, with a lot of potentials and that it is advancing quite quickly (Hager 27 et al. 2016; Stute et al. 2018; Wang et al. 2020). | 1515 - 1515 | | | |
| IPCC_AR6_WGIII_Full_Report | 28 29 9.3 New developments in emission trends and drivers 30 9.3.1 Past and future emission trends 31 Total GHG emissions in the building sector reached 12 GtCO2eq. in 2019, equivalent to 21% of global 32 GHG emissions that year. 57% of GHG emissions from buildings were indirect CO2 emissions from 33 generation of electricity and heat off-site, 24% were direct CO2 emissions produced on-site, and 18% 34 were from the production of cement and steel used for construction and refurbishment of buildings 35 (Figure 9.3a) (see Cross-Chapter Box 3 and Cross-Working Group Box 1 in Chapter 3). Halocarbon 36 emissions were equivalent to 3% of global building GHG emissions in 2019. In the absence of the 37 breakdown of halocarbon emissions per end-use sectors, they have been calculated for the purpose of 38 this chapter, by considering that 60% of global halocarbon emissions occur in buildings (Hu et al. 2020). | 1517 - 1517 | | | |
| IPCC_AR6_WGIII_Full_Report | 5 The literature evaluating the embodied energy in building materials is extensive, but that considering 6 embodied carbon is much more scarce (Cabeza et al. 2021). Recently this evaluation is done using the 7 methodology life cycle assessment (LCA), but since the boundaries used in those studies are different, 8 varying for example, in the consideration of cradle to grave, cradle to gate, or cradle to cradle, the 9 comparison is very difficult (Moncaster et al. 2019). A summary of the embodied energy and embodied 10 carbon cradle to gate coefficients reported in the literature are found in Figure 9.9 (Alcorn and Wood 11 1998; Birgisdottir et al. 2017; Cabeza et al. 2013; De Wolf et al. 2016; Symons 2011; Moncaster and 12 Song 2012; Omrany et al. 2020; Pomponi and Moncaster 2016, 2018; Crawford and Treolar 2010; 13 Vukotic et al. 2010; Cabeza et al. 2021). Steel represents the materials with higher embodied energy, 32-35 MJ·kg-1 14 ; embodied energy in masonry is higher than in concrete and earth materials, but 15 surprisingly, some type of wood have more embodied energy than expected; there are dispersion values 16 in the literature depending of the ma. On the other hand, earth materials and wood have the lowest 17 embodied carbon, with less than 0.01 kg CO2 per kg of material (Cabeza et al. 2021). The concept of 18 buildings as carbon sinks raise from the idea that wood stores considerable quantities of carbon with a 19 relatively small ratio of carbon emissions to material volume and concrete has substantial embodied 20 carbon emissions with minimal carbon storage capacity (Churkina et al. 2020; Sanjuán et al. 2019). | 1535 - 1535 | | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | 15 9.4.4.2 Historical and heritage buildings 16 Historical buildings, defined as those built before 1945, are usually low-performance buildings by 17 definition from the space heating point of view and represent almost 30–40% of the whole building 18 stock in European countries (Cabeza et al. 2018a). Historical buildings often contribute to townscape 19 character, they create the urban spaces that are enjoyed by residents and attract tourist visitors. They 20 may be protected by law from alteration not only limited to their visual appearance preservation, but 21 also concerning materials and construction techniques to be integrated into original architectures. On 22 the other hand, a heritage building is a historical building which, for their immense value, is subject to 23 legal preservation. The integration of renewable energy systems in such buildings is more challenging 24 than in other buildings. The review carried out by (Cabeza et al. 2018a) different case studies are 25 presented and discussed, where heat pumps, solar energy and geothermal energy systems are integrated 26 in such buildings, after energy efficiency is considered. | 1545 - 154 | Prot-Adapt-Mitig- | | |

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| IPCC_AR6_WGIII_Full_Report | 27 9.4.4.3 Positive energy or energy plus buildings 28 The integration of energy generation on-site means further contribution of buildings towards 29 decarbonisation (Ürge-Vorsatz et al. 2020). Integration of renewables in buildings should always come 30 after maximising the reduction in the demand for energy services through sufficiency measures and 31 maximising efficiency improvement to reduce energy consumption, but the inclusion of energy 32 generation would mean a step forward to distributed energy systems with high contribution from 33 buildings, becoming prosumers (Sánchez Ramos et al. 2019). Decrease price of technologies such as 34 PV and the integration of energy storage (de Gracia and Cabeza 2015) are essential to achieve this 35 objective. Other technologies that could be used are photovoltaic/thermal (Sultan and Ervina Efzan 36 2018), solar/biomass hybrid systems (Zhang et al. 2020b), solar thermoelectric (Sarbu and Dorca 2018), 37 solar powered sorption systems for cooling (Shirazi et al. 2018), and on-site renewables with battery 38 storage (Liu et al. 2021). | 1545 - 1545 | | | |
| IPCC_AR6_WGIII_Full_Report | 16 9.5.2.5 Value-chain, social and institutional innovations 17 Cooperative efforts are necessary to improve buildings energy efficiency (Masuda and Claridge 2014; 18 Kamilaris et al. 2014; Ruparathna et al. 2016). For instance, inter-disciplinary understanding of 19 organizational culture, occupant behaviour, and technology adoption is required to set up 20 occupancy/operation best practises (Janda 2014). Similarly, close collaboration of all actors along the 21 value chain can reduce by 50% emissions from concrete use (Habert et al. 2020); such collaboration 22 can be enhanced in a construction project by transforming the project organisation and delivery contract 23 to reduce costs and environmental impact (Hall and Bonanomi 2021). Building commissioning helps to 24 reduce energy consumption by streamlining the systems, but benefits may not persistent. Energy 25 communities are discussed later in the chapter. | 1552 - 155 | Impact | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 9 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 9-51 Total pages: 168 1 Table 9.3 Reasons for adoption of climate mitigation solutions. The sign represents if the effect is positive 2 (+) or negative (-), and the number of signs represents confidence level (++, many references; +, few 3 references) (Mata et al. 2021a) Climate mitigation solutions for buildings Building envelope Efficient technical systems On-site renewable energy Behaviour Performance standards Low-carbon materials Digitalization and flexibility Circular and sharing econ. | 1552 - 155 | 'rot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGIII_Full_Report | 8 Motivations are often triggered by urgent comfort or replacement needs. Maintaining the aesthetic value 9 may as well hinder the installation of insulation if no technical solutions are easily available (Haines 10 and Mitchell 2014; Bright et al. 2019). Local professionals and practitioners can both encourage 11 (Ozarisoy and Altan 2017; Friege 2016) and discourage the installation of insulation, according to their 12 knowledge and training (Maxwell et al. 2018; Curtis et al. 2017; Zuhaib et al. 2017; Tsoka et al. 2018). | 1554 - 1554 | | | |
| IPCC_AR6_WGIII_Full_Report | 4 Government support is needed an initiator but also to reinforce building retrofft targets, promote more 5 stringent energy and material standards for new constructions, and protect consumer interests 6 (Hongping 2017; Fischer and Pascucci 2017; Patwa et al. 2020). Taxes clearly incentivize waste 7 reduction and recycling (Ajayi et al. 2015; Rachel and Travis 2011; Volk et al. 2019). In developing 8 countries, broader, international, market boundaries can allow for a more attractive business model 9 (Mohit et al. 2020). Participative and new ownership models can favour the adoption of prefabricated 10 buildings (Steinhardt and Manley 2016). Needs for improvements are observed, in terms of design for 11 flexibility and deconstruction, procurement and prefabrication and off-site construction, standardization 12 and dimensional coordination, with differences among solutions (Ajayi et al. 2017)(Schiller et al, 13 2015,2017; Osmani, 2012; Lu and Yuan, 2013; Cossu and Williams, 2015; Bakshan et al 2017; Coehlo 14 et al 2013). | 1556 - 155 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGIII_Full_Report | 15 Although training is a basic requirement, attitude, past experience, and social pressure can also be highly 16 relevant, as illustrated for waste management in a survey to construction site workers (Amal et al. 2017). | 1556 - 1556 | | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | 17 Traditional community practices of reuse of building elements are observed to be replaced by a culture 18 of waste (Hongping 2017; Ajayi et al. 2015). | 1556 - 1556 | | INTANBILE | |

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| IPCC_AR6_WGIII_Full_Report | 25 Changes in cloud formation can affect global solar irradiation and, therefore, the output of solar 26 photovoltaic panels, possibly affecting on-site renewable energy production (Burnett et al. 2014). The 27 efficiency of solar photovoltaic panels and their electrical components decreases with higher 28 temperatures (Simioni and Schaeffer 2019) (Bahaidarah et al. 2013). However, studies have found that 29 such effect can be relatively small (Totschnig et al. 2017), making solar PV a robust option to adapt to 30 climate change (Shen and Lior 2016; Santos and Lucena 2021) (see Section 9.4). | 1568 - 156 | 'rot-Adapt-Mitig-Impa | | |
| IPCC_AR6_WGIII_Full_Report | 25 2020) (see Section 9.4, Figure 9.11 and Tables SM9.1 to SM9.3). This can also be achieved with on- 26 site renewable energy production, especially solar PV for which there can be a timely correlation 27 between power supply and cooling demand, improving load matching (Salom et al. 2014; Grove-Smith 28 et al. 2018). | 1569 - 1569 | | | |
| IPCC_AR6_WGIII_Full_Report | 26 Also, energy efficiency, sufficiency and on-site renewable energy production can help to increase 27 building resilience to climate change impacts and reduce pressure on the energy system. | 1570 - 157 | Impact | | |
| IPCC_AR6_WGIII_Full_Report | 44 45 9.9 Sectoral barriers and policies 46 9.9.1 Barriers, feasibility, and acceptance 47 Understanding the reasons why cost-effective investment in building energy efficiency are not taking 48 place as expected by rational economic behaviour is critical to design effective policies for decarbonize 49 the buildings (Cattaneo 2019; Cattano et al. 2013). Barriers depend from the actors (owner, tenant, 50 utility, regulators, manufacturers, etc.), their role in energy efficiency project and the market, ACCEPTED VERSION SUBJECT TO FINAL EDITS Final Government Distribution Chapter 9 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 9-80 Total pages: 168 1 technology, financial economic, social, legal, institutional, regulatory and policy structures (Reddy 2 1991; Weber 1997; Sorrell et al. 2000; Reddy 2002; Sorrell et al. 2011: Cagno et al. 2012; Bardhan et 3 al., 2014; Bagaini et al. 2020; Vogel et al. 2015; Khosla et al. 2017; Gupta et al. 2017). Barriers 4 identified for the refurbishment of exiting building or construction of new efficient buildings includes: 5 lack of high-performance products, construction methods, monitoring capacity, investment risks, 6 policies intermittency, information gaps, principal agent problems (both tenant and landlord face 7 disincentives to invest in energy efficiency), skills of the installers, lack of a trained and ready 8 workforce, governance arrangements in collectively owned properties and behavioural anomalies. (Do 9 et al. 2020; Dutt 2020; Gillingham and Palmer 2014;Yang et al., 2019; Song et al. 2020; Buessler et al. | 1581 - 158 | Impact | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | 24 Progressive building energy codes include requirements on efficiency improvement but also on 25 sufficiency and share of renewables (Rosenberg at al., 2017; Clune at al. 2012) and on embodied 26 emissions (Schwarz et al. 2020), for example the 2022 ASHRAE Standard 90.1 includes prescriptive 27 on-site renewable energy requirements for non-residential building. Evans et al. (2017; 2018) calls for 28 strengthen the compliance checks with efficiency requirements or codes when buildings are in operation 29 and highlighted the need for enforcement of building energy codes to achieve the estimate energy and 30 carbon savings recommending actions to improve enforcements, including institutional capacity and 31 adequate resources. | 1586 - 1586 | | | |
| IPCC_AR6_WGIII_Full_Report | 25 The concept of carbon allowances or carbon budget can also be applied to buildings, by assigning a 26 yearly CO2 emissions budget to each building. This policy would be a less complex than personal 27 allowances as buildings have metered or billed energy sources (e.g., gas, electricity, delivered heat, 28 heating oil, etc.). The scheme stimulates investments in energy efficiency and on-site renewable 29 energies and energy savings resulting from behaviour by buildings occupant. For commercial buildings, 30 similar schemes were implemented in the UK CRC Energy Efficiency Scheme (closed in 2019) or the 31 Tokyo Metropolitan Carbon and Trade Scheme (Nishida and Hua 2011)(Bertoldi et al. 2013a). The 32 Republic of Korea implemented since 2015 an Emission Trading Scheme, covering buildings (Park and 33 Hong 2014; Narassimhan et al. 2018; Lee and Yu 2017). More recently under the New York Climate 34 Mobilization Act enacted in 2019 New York City Local Law 97 established "Carbon Allowances" for 35 large buildings (Spiegel-Feld, 2019; Lee, 2020). | 1589 - 1589 | | | |
| IPCC_AR6_WGIII_Full_Report | 40 9.9.5 Policies mechanisms for financing for on-site renewable energy generation 41 On-site renewable energy generation is a key component for the building sector decarbonisation, 42 complementing sufficiency and efficiency. Renewable energies (RES) technologies still face barriers 43 due to the upfront investment costs, despite the declining price of some technologies, long pay-back 44 period, unpredictable energy production, policy incertitude, architectural (in particular for built-in PV) 45 and landscape considerations, technical regulations for access to the grid, and future electricity costs 46 (Mah et al. 2018; Agathokleous and Kalogirou 2020). | 1592 - 1592 | | | |

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| IPCC_AR6_WGIII_Full_Report | 16 A flat rate feed-in tariff (FiT) is a well-tested incentive adopted in many jurisdictions to encourage end- 17 users to generate electricity from RES using rooftop and on-site PV systems (Pacudan 2018). More 18 recently, there has been an increasing interest for dynamic FiTs taking into account electricity costs, 19 hosting capacity, ambient temperature, and time of day (Hayat et al. 2019). Since 2014, EU Member 20 States have been obligated to move from FiT to feed-in premium (FiTP) (Hortay and Rozner 2019); 21 where a FiTP consist in a premium of top of the electricity market price. Lecuyer and Quirion (2019) 22 argued that under uncertainty over electricity prices and renewable production costs a flat FiT results 23 in higher welfare than a FiTP. One of the main concerns with FiT systems is the increasing cost of 24 policies maintenance (Pereira da Silva et al. 2019; Roberts et al. 2019a; Zhang et al. 2018). In Germany, 25 the financial costs, passed on to consumers in the form a levy on the electricity price have increased 26 substantially in recent years (Winter and Schlesewsky 2019) resulting in opposition to the FiT in 27 particular by non-solar customers. A particular set up of the FiT encourage self-consumption through 28 net metering and net billing, which has a lower financial impact on electricity ratepayers compared with 29 traditional FiTs (Roberts et al. 2019b; Vence and Pereira 2019; Pacudan 2018). | 1593 - 159 | Impact | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | 11 Tenders are a fast spreading and effective instrument to attract and procure new generation capacity 12 from renewable energy sources (Bayer et al. 2018; Bento et al. 2020; Ghazali et al. 2020; Haelg 2020; 13 Batz T. and Musgens 2019). A support scheme based on tenders allows a more precise steering of 14 expansion and lower risk of excessive support (Gephart et al. 2017). Bento et al. (2020) indicated that 15 tendering is more effective in promoting additional renewable capacity comparing to other mechanisms 16 such as FiTs. It is also important to take into account the rebound effect in energy consumption by on- 17 site PV users, which might reduce up to one fifth of the carbon benefit of renewable energy (Deng and 18 Newton 2017). | 1594 - 159 | Impact | | |
| IPCC_AR6_WGIII_Full_Report | 39 Building energy consumption is dependent on local climate and building construction traditions, 40 regional and local government share an important role in promoting energy efficiency in buildings and 41 on-site RES, through local building energy codes, constructions permits and urban planning. In South 42 Korea, there is a green building certification system operated by the government, based on this, Seoul 43 has enacted Seoul's building standard, which includes more stringent requirements. Where it is difficult 44 to retrofit existing buildings, e.g., historical buildings, cities may impose target at district level, where 45 RES could be shared among buildings with energy positive buildings compensating for energy 46 consuming buildings. Local climate and urban plans could also contribute to the integration of the 47 building sector with the local transport, water, and energy sectors, requiring, for example, new 48 constructions in areas served by public transport, close to offices or buildings to be ready for e-mobility. | 1596 - 1596 | | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | 25 There are three categories of GHG emissions from buildings: 26 i. direct emissions which are defined as all on-site fossil fuel or biomass-based combustion 27 activities (i.e., use of biomass for cooking, or gas for heating and hot water) and F-gas emissions 28 (i.e., use of heating and cooling systems, aerosols, fire extinguishers, soundproof) 29 ii. indirect emissions which occur off-site and are related to heat and electricity production 30 iii. embodied emissions which are related to extracting, producing, transforming, transporting, and 31 installing the construction material and goods used in buildings 32 In 2019, global GHG emissions from buildings were at 12 GtCO2-eq out of which 24% were direct 33 emissions, 57% were indirect emissions, and 18% were embodied emissions. More than 95% of 34 emissions from buildings were CO2 emissions, CH4 and N2O represented 0.08% each and emissions 35 from halocarbon contributed by 3% to global GHG emissions from buildings. | 1599 - 1599 | | | |

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| IPCC_AR6_WGIII_Full_Report | 38 Mitigation actions in buildings generate multiple co-benefits (e.g., health benefits due to the improved 39 indoor and outdoor conditions, productivity gains in non-residential buildings, creation of new jobs 40 particularly at local level, improvements in social wellbeing etc.) beyond their direct impact on reducing 41 energy consumption and GHG emissions. Most studies agree that the value of these multiple benefits 42 is greater than the value of energy savings and their inclusion in economic evaluation of mitigation ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 9 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 9-98 Total pages: 168 1 actions may improve substantially their cost-effectiveness. It is also worth mentioning that in several 2 cases the buildings sector is characterized by strong rebound effects, which could be considered as a 3 co-benefit in cases where the mechanisms involved provide faster access to affordable energy but also 4 a trade-off in cases where the external costs of increased energy consumption exceed the welfare 5 benefits of the increased energy service consumption, thus lowering the economic performance of 6 mitigation actions. The magnitude of these co-benefits and trade-offs are characterized by several 7 uncertainties, which may be even higher in the future as mitigation actions will be implemented in a 8 changing climate, with changing building operation style and occupant behaviour. Mitigation measures 9 influence the degree of vulnerability of buildings to future climate change. For instance, temperature 10 rise can increase energy consumption, which may lead to higher GHG emissions. Also, sea level rise, 11 increased storms and rainfall under future climate may impact building structure, materials and 12 components, resulting in increased energy consumption and household expenditure from producing and 13 installing new components and making renovations. Well-planned energy efficiency, sufficiency and 14 on-site renewable energy production can help to increase building resilience to climate change impacts 15 and reduce adaptation needs. | 1599 - 160 | 'rot-Adapt-Mitig-Impa | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | 18 Several barriers (information, financing, markets, behavioural, etc.) still prevents the decarbonisation 19 of buildings stock, despite the several co-benefits, including large energy savings. Solutions include 20 investments in technological solutions (e.g., insulation, efficient equipment, and low-carbon energies 21 and renewable energies) and lifestyle changes. In addition, the concept of sufficiency is suggested to be 22 promoted and implemented through policies and information, as technological solutions will be not 23 enough to decarbonise the building sector. Due to the different types of buildings, occupants, and 24 development stage there is not a single policy, which alone will reach the building decarbonisation 25 target. A range of policy instruments ranging from regulatory measures such as building energy code 26 for NZEBs and appliance standards, to market-based instruments (carbon tax, personal carbon 27 allowance, renewable portfolio standards, etc.), and information. Financing (grants, loans, performance 28 base incentives, pays as you save, etc.) is another key enabler for energy efficiency technologies and 29 on-site renewables. Finally, effective governance and strong institutional capacity are key to have an 30 effective and successful implementation of policies and financing. | 1600 - 160 | Impact | | |
| IPCC_AR6_WGIII_Full_Report | 22 {10.3, 10.8} 23 Legislated climate strategies are emerging at all levels of government, and, together with pledges 24 for personal choices, could spur the deployment of demand and supply-side transport mitigation 25 strategies (medium confidence). At the local level, legislation can support local transport plans that 26 include commitments or pledges from local institutions to encourage behaviour change by adopting an 27 organisational culture that motivates sustainable behaviour with inputs from the creative arts. Such 28 institution-led mechanisms could include bike-to-work campaigns, free transport passes, parking 29 charges, or eliminating car benefits. Community-based solutions like solar sharing, community 30 charging, and mobility as a service can generate new opportunities to facilitate low-carbon transport 31 futures. At the regional and national levels, legislation can include vehicle and fuel efficiency standards, 32 R&D support, and large-scale investments in low-carbon transport infrastructure. {10.8, Chapter 15} 33 34 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 10 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 10-7 Total pages: 176 1 10.1 Introduction and overview 2 This chapter examines the transport sector's role in climate change mitigation. It appraises the transport 3 system's interactions beyond the technology of vehicles and fuels to include the full life cycle analysis 4 of mitigation options, a review of enabling conditions, and metrics that can facilitate advancing 5 transport decarbonisation goals. The chapter assesses developments in the systems of land-based 6 transport and introduces, as a new feature since AR5, two separate sections focusing on the trends and 7 challenges in aviation and shipping. The chapter assesses the future trajectories emerging from global, 8 energy, and national scenarios and concludes with a discussion on enabling conditions for 9 transformative change in the sector. | 1676 - 167 | Prot-Adapt-Mitig- | | |

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| IPCC_AR6_WGIII_Full_Report | 35 While much attention has been given to engine and fuel technologies to mitigate GHG emissions from 36 the transport sector, population dynamics, finance and economic systems, urban form, culture, and 37 policy also drive emissions from the sector. Thus, systemic change requires innovations in these 38 components. These systemic changes offer the opportunity to decouple transport emissions from 39 economic growth. In turn, such decoupling allows environmental improvements like reduced GHG 40 emissions without loss of economic activity (UNEP 2011, 2013; Newman et al. 2017; IPCC 2018). | 1683 - 168 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGIII_Full_Report | 19 Avoid - the effect of prices and income on demand: Research has shown that household income and 20 price have a strong influence on people's preferences for transport services (Bakhat et al. 2017; Palmer 21 et al. 2018). The relationship between income and demand is defined by the income elasticity of 22 demand. For example, research suggests that in China, older and wealthier populations continued to 23 show a preference for car travel (Yang et al. 2019) while younger and low-income travellers sought 24 variety in transport modes (Song et al. 2018). Similarly, (Bergantino et al. 2018b) evaluated the income 25 elasticity of transport by mode in the UK. They found that the income elasticity for private cars is 0.714, 26 while the income elasticities of rail and bus use are 3.253 (The greater elasticity the greater the demand 27 will grow or decline, depending on income). Research has also shown a positive relationship between 28 income and demand for air travel, with income elasticities of air travel demand being positive and as 29 large as 2 (Gallet and Doucouliagos 2014; Valdes 2015; Hakim and Merkert 2016, 2019; Hanson et al. | 1686 - 168 | Impact | | |
| IPCC_AR6_WGIII_Full_Report | 18 There is growing evidence that this more structured form of behavioural change through shared 19 economy practices, supported by a larger group than a single family, has a much greater potential to 20 save transport emissions, especially when complemented with decarbonised grid electricity (Greenblatt 21 and Shaheen 2015; Sharp 2018). Carpooling, for example, could result in an 11% reduction in vkm and 22 a 12% reduction in emissions, as carpooling requires less empty or non-productive passenger- 23 kilometres (pkm) (ITF 2020a,b). However, the use of local shared mobility systems such as on-demand 24 transport may create more transport emissions if there is an overall modal shift out of transit (ITF 2018a; 25 Schaller 2018). Similarly, some work suggests that commercial shared vehicle services such as Uber 26 and Lyft are leading to increased vehicle kms travelled (and associated GHG emissions) in part due to 27 deadheading (Schaller 2018; Tirachini and Gomez-Lobo 2020; Ward et al. 2021). Successful providers 28 compete by optimising personal comfort and convenience rather than enabling a sharing culture 29 (Eckhardt and Bardhi 2015), and concerns have been raised regarding the wider societal impacts of 30 these systems and for specific user groups such as older people (Fitt 2018; Marsden 2018). Concerns 31 have also been expressed over the financial viability of demand-responsive transport systems (Ryley et 32 al. 2014; Marsden 2018), how the mainstreaming of shared mobility systems can be institutionalised 33 equitably, and the operation and governance of existing systems that are only mode and operator- 34 focused (Akyelken et al. 2018; Jittrapirom et al. 2018; Pangbourne et al. 2020; Marsden 2018). | 1689 - 168 | Impact | | |
| IPCC_AR6_WGIII_Full_Report | 16 2018). All three of these technologies rely on making use of relatively inexpensive elements, which can 17 help bring down battery costs (Cano et al. 2018). The main challenge these technologies face is in terms 18 of the cycle life. Out of the three, Li-S has already been used for applications in unmanned aerial 19 vehicles (Fotouhi et al., 2017) due to relatively high specific energy (almost double the state of art 20 LIBs). However, even with low cycle life, Li-air and Zn-air hold good prospects for commercialisation 21 as range extender batteries for long-range road transport and with vehicles that are typically used for 22 city driving (Cano et al. 2018). | 1702 - 1702 | | | |
| IPCC_AR6_WGIII_Full_Report | 22 Ammonia, synthetic fuels, and biofuels have emerged as alternative fuels for powering combustion 23 engines and turbines used in land, shipping, and aviation (Figure 10.2). Synthetic fuels such as e- 24 Methanol and Fischer-Tropsch liquids have similar physical properties and could be used with existing 25 fossil fuel infrastructure (Soler, 2019). Similarly, biofuels have been used in several countries together 26 with fossil fuels (Panoutsou et al. 2021). Ammonia is a liquid, but only under pressure, and therefore 27 will not be compatible with liquid fossil fuel refuelling infrastructure. Ammonia is, however, widely 28 used as a fertiliser and chemical raw material and 10% of annual Ammonia production is transported 29 via sea (Gallucci 2021). As such, a number of port facilities include Ammonia storage and transport 30 infrastructure and the shipping industry has experience in handling Ammonia (Gallucci 2021). This 31 infrastructure would likely need to be extended in order to support the use of Ammonia as a fuel for 32 shipping and therefore ports are likely to be the primary sites for these new refuelling facilities. | 1704 - 1704 | | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGIII_Full_Report | 15 While charging infrastructure is of high importance for the electrification of light-duty vehicles, 16 arguably, it is even more important for heavy-duty vehicles given the costs of high-power charging 17 infrastructure. It is estimated that the installed cost of fast-charging hardware can vary between 18 approximately USD 45,000 to 200,000 per charger, depending on the charging rate, the number of 19 chargers per site, and other site conditions (Nicholas 2019; Hall and Lutsey 2019; Nelder and Rogers 20 2019). Deployment of shared charging infrastructure at key transport hubs, such as bus and truck depots, 21 freight distribution centres, marine shipping ports and airports, can encourage a transition to electric 22 vehicles across the heavy transport segments. Furthermore, if charging infrastructure sites are designed 23 to cater for both light and heavy-duty vehicles, infrastructure costs could decrease by increasing 24 utilisation across multiple applications and/or fleets (Nelder and Rogers 2019). | 1705 - 1705 | | | |
| IPCC_AR6_WGIII_Full_Report | 3 The design of Hydrogen refuelling stations depends on the choice of methods for Hydrogen supply and 4 delivery, compression and storage, and the dispensing strategy. Hydrogen supply could happen via on- 5 site production or via transport and delivery of Hydrogen produced off-site. At the compression stage, 6 Hydrogen is compressed to achieve the pressure needed for economic stationery and vehicle storage. | 1707 - 1707 | | | |
| IPCC_AR6_WGIII_Full_Report | 11 If Hydrogen is produced off site in a large centralised plant, it must be stored and delivered to refuelling 12 stations. The cost of Hydrogen delivery depends on the amount of Hydrogen delivered, the delivery 13 distance, the storage method (compressed gas or cryogenic liquid), and the delivery mode (truck vs. | 1707 - 1707 | | | |
| IPCC_AR6_WGIII_Full_Report | 14 pipeline). Table 10.6 describes the three primary options for Hydrogen delivery. Most Hydrogen 15 refuelling stations today are supplied by trucks and, very occasionally, Hydrogen pipelines. Gaseous 16 tube trailers could also be used to deliver Hydrogen in the near term, or over shorter distances, due to 17 the low fixed cost (although the variable cost is high). Both liquefied truck trailers and pipelines are 18 recognised as options in the medium to long-term as they have higher capacities and lower costs over 19 longer distances (FCHJU 2019; Li et al. 2020; EU 2021).Alternatively, Hydrogen can be produced on 20 site using a small-scale onsite electrolyser or steam methane reforming unit combined with CCS. | 1707 - 1707 | | | |
| IPCC_AR6_WGIII_Full_Report | 9 FCVs represent the most expensive solution for LDV, mainly due to the currently higher purchase price 10 of the vehicle itself. However, given the lower technology readiness level of FCVs and the current 11 efforts in the research and development of this technology, FCVs could become a viable technology for 12 LDVs in the coming years. The issues regarding the extra energy involved in creating the Hydrogen 13 and its delivery to refuelling sites remain, however. The levelized cost of Hydrogen on a per GJ basis 14 is lower than conventional fossil fuels but higher than electricity. In addition, within the levelized cost 15 of Hydrogen, there are significant cost differences between the Hydrogen producing technologies. | 1716 - 1716 | | | |
| IPCC_AR6_WGIII_Full_Report | 13 14 Figure 10.8 presents a review of life cycle GHG emissions from land-based freight technologies (heavy 15 and medium-duty trucks, and rail). Each panel within the figure represents data in GHG emissions per 16 tkm of freight transported by different technology and/or fuel types, as indicated by the labels to the 17 left. The data in each panel came from a number of relevant scientific studies (Merchan et al. 2020; 18 Frattini et al. 2016; Zhao et al. 2016; CE Delft 2017; Isaac and Fulton 2017; Song et al. 2017; Cooper 19 and Balcombe 2019; S. Mojtaba et al. 2019; Nahlik et al. 2016; Prussi et al. 2020; Hill et al. 2020; Liu 20 et al. 2020a; Valente et al. 2021; Gray et al. 2021; Valente et al. 2017; Tong et al. 2015a). Similar to 21 the results for buses, technologies that offer substantial emission reductions for freight include: ICEV 22 trucks powered with the low carbon variants for biofuels, Ammonia or synthetic diesel; BEVs charged 23 with low carbon electricity; and FCVs powered with renewable-based electrolytic Hydrogen, or 24 Ammonia. Since Ammonia and Fischer-Tropsch diesel are produced from Hydrogen, their emissions 25 are higher than the source Hydrogen, but their logistical advantages over Hydrogen are also a 26 consideration (as discussed in Section 10.3). | 1724 - 1724 | | INTANBILE | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGIII_Full_Report | 25 Increased Arctic shipping activity may also impose increased risks to local marine ecosystems and 26 coastal communities from invasive species, underwater noise, and pollution (Halliday et al. 2017; IPCC 27 2019). Greater levels of Arctic maritime transport and tourism have political, as well as socio-economic 28 implications for trade, and nations and economies reliant on the traditional shipping corridors. There 29 has been an increase in activity from cargo, tankers, supply, and fishing vessels in particular (Zhao et 30 al. 2015; Winther et al. 2014). Projections indicate more navigable Arctic waters in the coming decades 31 (Smith and Stephenson 2013; Melia et al. 2016) and continued increases in transport volumes through 32 the northern sea routes (Winther et al. 2014; Corbett et al. 2010; Lasserre and Pelletier 2011). Emission 33 patterns and quantities, however, are also likely to change with future regulations from IMO, and 34 depend on technology developments, and activity levels which may depend upon geopolitics, 35 commodity pricing, trade, natural resource extractions, insurance costs, taxes, and tourism demand 36 (Johnston et al. 2017). The need to include indigenous peoples' voices when shaping policies and 37 governance of shipping activities in the high north is increasing (Dawson et al. 2020). | 1739 - 173 | Impact | INTANBILE | INDG |
| IPCC_AR6_WGIII_Full_Report | 28 Traditionally there is a disconnection between IAM models and bottom-up sectoral or city-based 29 models due to the different scale (both spatial and temporal) and focus (climate mitigation vs. urban 30 pollutions, safety (Creutzig 2016)). The proliferation of shared and on-demand mobility solutions are 31 leading to rebound effects for travel demand (Chen and Kockelman 2016; Coulombel et al. 2019) and 32 this is a new challenge for modelling. Some IAM studies have recently begun to explore demand-side 33 solutions for reducing transport demand to achieve very low-carbon scenarios through a combination 34 of culture and low-carbon lifestyle (Creutzig et al. 2018; van Vuuren et al. 2018); urban development 35 (Creutzig et al. 2015a); increased vehicle occupancy (Grubler et al. 2018); improved logistics and 36 streamline supply chains for the freight sector (Mulholland et al. 2018); and disruptive low-carbon 37 innovation, described as technological and business model innovations offering "novel value 38 propositions to consumers and which can reduce GHG emissions if adopted at scale" (Wilson et al. | 1752 - 175 | 'rot-Adapt-Mitig-Impac | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | 43 END BOX HERE 44 45 Enabling creative foresight: Human culture has always had a creative instinct that enables the future to 46 be better dealt with through imagination (Montgomery 2017). Science and engineering have often been ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 10 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 10-99 Total pages: 176 1 preceded by artistic expressions such as Jules Verne, who first dreamed of the Hydrogen future in 1874 2 in his novel The Mysterious Island. Autonomous vehicles have regularly occupied the minds of science 3 fiction authors and filmmakers (Braun 2019). Such narratives, scenario building, and foresighting are 4 increasingly seen as a part of the climate change mitigation process (Lennon et al. 2015; Muiderman et 5 al. 2020) and can 'liberate oppressed imaginaries' (Luque-Ayala 2018). (Barber 2021) have emphasised 6 the important role of positive images about the future instead of dystopian visions and the impossibility 7 of business-as-usual futures. | 1768 - 176 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGIII_Full_Report | 13 The state-of-the-art Lithium-Ion Batteries (LIBs) available in 2020 are superior to alternative cell 14 technologies in terms of battery life, energy density, specific energy, and cost. The expected further 15 improvements in LIBs suggest these chemistries will remain superior to alternative battery technologies 16 in the medium-term, and therefore LIBs will continue to dominate the electric vehicle market. | 1773 - 1773 | | | |
| IPCC_AR6_WGIII_Full_Report | However, blue hydrogen production pathways may generate air pollutants nearby the production sites. | 1837 - 1837 | | | |

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| IPCC_AR6_WGIII_Full_Report | 2 A common platform for sharing information and enhancing communication among industrial 3 stakeholders through the application of information and telecommunication technologies is helpful for 4 facilitating the creation of industrial symbiosis. The main benefit of industrial symbiosis is the overall 5 reduction of both virgin materials and final wastes, as well as reduced/avoided transportation costs from 6 byproduct exchanges among tenant companies, which can specifically help small and medium sized 7 enterprises to improve their growth and competitiveness. From climate perspective, this indicates 8 significant industrial emission mitigation since the extraction, processing of virgin materials and the 9 final disposal of industrial wastes are more energy-intensive. Also, careful site selection of such parks 10 can facilitate the use of renewable energy. Due to these advantages, eco-industrial parks have been 11 actively promoted, especially in East Asian countries, such as China, Japan and South Korea, where 12 national indicators and governance exist (Geng et al. 2019). For instance, the successful implementation 13 of industrial symbiosis at Dalian Economic and Technological Development Zone has achieved 14 significant co-benefits, including GHG emission reduction, economic and social benefits and improved 15 ecosystem functions (Liu et al. 2018). Another case at Ulsan industrial park, South Korea, estimated 16 that 60,522 tonnes CO2 were avoided annually through industrial symbiosis between two companies 17 (Kim et al. 2018b). The case of China shows a great potential of implementing these measures, 18 estimating 111 million tonne CO2 equivalent will be reduced in 213 national-level industrial parks in 19 2030 compared with 2015 (Guo et al. 2018). As such, South Korea's national eco-industrial park project 20 has reduced over 4.7 million tonne CO2 equivalent through their industrial symbiosis efforts (Park et al. | 1874 - 187 | Prot-Adapt-Mitig- | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | 17 There is a large identified potential for direct solar heating in industry, especially in regions with strong 18 solar insolation and sectors with lower heat needs (<180□C), for example, food and beverage processing, 19 textiles, and pulp and paper (Schoeneberger et al. 2020). The key challenges to adoption are site and 20 use specificity, capital intensity, and a lack of standardized, mass manufacturing for equipment and 21 supply chain to provide them. | 1878 - 1878 | | | |
| IPCC_AR6_WGIII_Full_Report | 23 There are several post-combustion CCS projects underway globally (IEA 2019g), generally focussed 24 on energy production and processing rather than industry. Their costs are higher but evolving downward – (Giannaris et al. 2020) suggest 47 USD·tCO2 -1 25 for a follow up 90% capture power generation plant 26 based on learnings from the Saskpower Boundary Dam pilot – but crucially these costs are higher than 27 implicit and explicit carbon prices almost everywhere, resulting in limited investment and learning in 28 these technologies. A key challenge with all CCS strategies, however, is building a gathering and 29 transport network for CO2, especially from dispersed existing sites; hence most pilot are built near 30 EOR/geological storage sites, and the movement towards industrial clustering in the EU and UK 31 (UKCCC 2019b), and as suggested in (IEA 2019f). | 1882 - 1882 | | | |
| IPCC_AR6_WGIII_Full_Report | 8 Circular economy introduces itself throughout, but mainly at the front end when designing materials 9 and processes to be more materially efficient, efficient in use, and easy to recycle, and at the back end, 10 when a material or product's services life has come to end, and it is time for recycling or sustainable 11 disposal (Korhonen et al. 2018; Murray et al. 2017). The entire chain's potential will be maximized 12 when these strategies are designed in ahead of time instead of considered on assembly, or as a retrofit 13 (Material Economics 2019; Allwood et al. 2012; Gonzalez Hernandez et al. 2018a; IEA 2019b; Bataille 14 2020a). For example, when designing a building: 1) Is the building shell, interior mass and ducting 15 orientated for passive heating and cooling, and can the shell and roof have building integrated solar PV 16 or added easily, with hard-to-retrofit wiring already incorporated? 2) Are steel and high quality concrete 17 only used where really needed (i.e. for shear, tension and compression strength), can sections be 18 prefabricated off-site, can other materials be substituted, such as wood? 3) Can the interior fittings be 19 built with easy to recycle plastics or other sustainably disposable materials (e.g. wood)? 4) Can this 20 building potentially serve multiple purposes through its anticipated lifetime, are service conduits 21 oversized and easy to access for retrofitting? 5) When it is time to be taken apart, can pieces be reused, 22 and all componnents recycled at high purity levels, for example, can all the copper wiring be easily be 23 found and removed, are the steel beams clearly tagged with their content? The answers to these 24 questions will be very regionally and site specific, and require revision of educational curricula for the 25 entire supply chain, as well as revision of building codes. | 1885 - 1885 | | | |
| IPCC_AR6_WGIII_Full_Report | 23 Reflecting the different conditions at existing and potential future plant sites, when choosing one of the 24 above options a combination of different measures and structural changes (including electricity, 25 hydrogen and CCU or CCS infrastructure needs) will likely be necessary in the future to achieve deep 26 reductions in CO2 emissions of steel production. | 1891 - 1891 | | | |

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| IPCC_AR6_WGIII_Full_Report | Hydrogen as CH4 replacement <=10% 9 See above Today Biogas or liquid replacement hydrocarbons 60–90% 9 Biomass USD/GJ; >=50 USD/t, uncertain Today Anaerobic digestion/fermentation: CH4, CH3OH, C2H5OHxii Up to -99% 9 Biomass cost Today Methane or methanol from H2 & COx (CCUS for excess). Maximum -50% reduction if C source is FF 50–99% 6–9 Cost: H2 & COx Today 850°C woody biomass gasification w/ CCS for excess carbon: CO, CO2, H2, H2O, CH4, C2H4 & C6H6 xiii Could be negative 7–8 about 50–75 USD/t, uncertain Today Direct air capture for short and long chain CoOxHy xiv Up to 99% 3 Cost: E, H2, COx about 94–232 USD/t <=2030 1 i Data for CCS costs for steel making: Birat (2012); Axelson et al. (2018) and Leeson et al. (2017); ii Data for Hisarna: Axelson et al. (2018); iii Data for hydrogen DRI electric arc furnaces: Fischedick et al. (2014b) and Vogl et al. (2018); iv Data for molten oxide electrolysis (also known as SIDERWIN): (Axelson et al. 2018; Fischedick et al. 2014b). The TRLs differ by source, the value provided is from Axelson et al. (2018) based on UCLOS SIDERWIN; v Data for making hydrogen from SMR and ATR with CCUS: Moore (2017), Leeson et al. (2017) and IEA (2019f). The cost of CCS disposal of concentrated sources of CO2 at 15–40 USD·tCO2-eq-1 is well established as commercial for direct or EOR purposes and is based on the long standing practise of disposing of hydrogen sulfide and oil brines underground: Wilson et al. (2003) and Leeson et al. (2017). There is a wide variance, however, in estimated tCO2-eq-1 breakeven prices for industrial post-combustion capture of CO2 from sources highly diluted in nitrogen (e.g. Leeson et al. (2017) at 60–170 USD·tCO2-eq-1 ), but most fall under 120 USD·tCO2-eq-1 ; vi Data for clinker substitution and use of well mixed and multi sized aggregates: (Fechner and Kray 2012; Lehne and Preston 2018; Habert et al. 2020); vii Rio Tinto, Alcoa and Apple have partnered with the governments of Québec and Canada to formed a coalition to commercialize inert as opposed to sacrificial graphite electrodes by 2024, thereby making the standard Hall Heroult process very low emissions if low carbon electricity is used; viii Data and other information: Bazzanella and Ausfelder (2017); Axelson et al. (2018); IEA (2018a); De Luna et al. (2019) and Philibert (2017b,a); ix See De Luna et al. (2019) for a state of the art review of electrocatalysis, or direct recombination of organic molecules using electricity and catalysts; x Data for hydrogen production from electrolysis: Bazzanella and Ausfelder (2017); Philibert (2017a); Armijo and Philibert (2020); IEA (2019f); Philibert (2017b); xi Data for methane pyrolysis to make hydrogen: Abbas and Wan Daud (2010). Data for hydrogen production from methane catalytic cracking: Amin et al. (2011) and Ashik et al. (2015); xii Data for anaerobic digestion or fermentation for the production of methane, methanol and ethanol: De Luna et al. (2019); xiii Data for woody biomass gasification: Li et al. (2019) and van der Meijden et al. (2011); xiv Data on direct air capture of CO2: Keith et al. (2018) and Fasihi et al. (2019). | 1903 - 1903 | | | |
| IPCC_AR6_WGIII_Full_Report | 35 Using industrial waste heat for space heating, via district heating, is an established practice that still has 36 a large potential with large quantities of low-grade heat being wasted (Fang et al. 2015). For Denmark 37 it is estimated that 5.1% of district heating demand could be met with waste heat (Bühler et al. 2017) 38 and for four towns studied in Austria 3-35% of total heat demand could be met (Karner et al. 2016). A 39 European study shows that temporal heat demand flexibility could allow for up to 100% utilization of 40 excess heat from industry (Karner et al. 2018). A study of a Swedish chemicals complex estimated that 41 30-50% of excess heat generated on-site could be recovered with payback periods below 3 years 42 (Eriksson et al. 2018). | 1921 - 1921 | | | |
| IPCC_AR6_WGIII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 11 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 11-76 Total pages: 135 1 With increasing shares of renewable electricity production there is a growing interest in industrial 2 demand response, storage and hybrid solutions with on-site PV and CHP (Schriever and Halstrup 2018; 3 Scheubel et al. 2017; Shoreh et al. 2016). With future industrial electrification, and in particular with 4 hydrogen used as reduction agent in ironmaking or as feedstock in the chemicals industry, the level of 5 interaction between industry and power systems becomes very high. Large amounts of coking coal, or 6 oil and gas as petrochemical energy and feedstock, are then replaced by electricity. For example, Meys 7 et al. (2021) estimates a staggering future electricity demand of 10,000 TWh in a scenario for a net zero 8 emissions plastics production of 1100 Mt in 2050 (see 11.3.5 for other estimates of electricity demand). | 1921 - 1922 | | | |
| IPCC_AR6_WGIII_Full_Report | 18 Many studies report that energy efficiency improvements are essential for supporting overall economic 19 growth, contributing to positive changes in multi-factor productivity (SDG 8 - Decent Work and 20 Economic Growth & Industry, Innovation, and Infrastructure) (Bashmakov 2019; Bataille and Melton 21 2017; Stern 2019; Lambert et al. 2014; Rajbhandari and Zhang 2018) through industrial innovation 22 (SDG 9) (Kang and Lee 2016), with some dissent e.g., (Mahmood and Ahmad 2018). Improved energy 23 efficiency against a background of growing energy prices helps industrial plants stay competitive 24 (Bashmakov and Myshak 2018). Energy efficiency allows continued economic growth under strong 25 environmental regulation. Given that energy efficiency measures reduce the combustion of fossil fuels 26 it leads to reduced air pollution at industrial sites (Williams et al. 2012) and better indoor comfort at 27 working places. | 1928 - 1928 | | | |

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| --- | --- | --- | --- | --- | --- |
| IPCC_AR6_WGIII_Full_Report | 14 Assessments of pricing mechanisms show generally that they lead to reduced emissions, even in sectors 15 that receive free allocation such as industry (Bayer and Aklin 2020; Narassimhan et al. 2018; Martin et 16 al. 2016; Haites et al. 2018; Metcalf 2019). However, questions remain as to whether these schemes 17 can bring emissions down fast enough to reach the Paris Agreement goals (World Bank Group 2019; 18 Tvinnereim and Mehling 2018; Boyce 2018b). Most carbon prices are well below the levels needed to 19 motivate investments in high-cost options that are needed to reach net zero emissions (see Section 20 11.4.1.5). Among the 64 carbon price schemes implemented worldwide today, only nine have carbon 21 prices above 40 USD (World Bank 2020). These are all based in Europe and include EU Emissions 22 Trading System (ETS) (above 40 USD since March 2021), Switzerland ETS, and seven countries with 23 carbon taxes. Furthermore, emissions-intensive and trade-exposed (EITE) industries are typically 24 allowed exemptions and receive provisions that shelter them from any significant cost increase in ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 11 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 11-86 Total pages: 135 1 virtually all pricing schemes (Haites 2018). These provisions have been allocated due to concerns about 2 loss of competitiveness and carbon leakage which result from relocation and increased imports from 3 jurisdictions with no, or weak, GHG emission regulations (Branger and Quirion 2014a; Jakob 2021a; 4 Branger and Quirion 2014b). Embodied emissions in international trade accounts for one quarter of 5 global CO2 emissions in 2015 (Moran et al. 2018) and has increased significantly over the past few 6 decades, representing a significant challenge to competitiveness related to climate policy. CBAM, or 7 CBA) are trade-based mechanisms designed to 'equalise' the carbon costs for domestic and foreign 8 producers. They are increasingly being considered by policy makers to address carbon leakage and 9 create a level playing field for products produced in jurisdiction with no, or lower, carbon price 10 (Mehling et al. 2019; Markkanen et al. 2021). On 14 July 2021, the European Commission adopted a 11 proposal for a CBAM that requires importers of aluminium, cement, iron and steel, electricity and 12 fertiliser to buy certificates at the ETS price for the emissions embedded in the imported products 13 (European Commission 2021; Mörsdorf 2021). CBAMs should be crafted very carefully, to meet 14 technical and legal challenges (Rocchi et al. 2018; Sakai and Barrett 2016; Jakob et al. 2014; Cosbey et 15 al. 2019; Pyrka et al. 2020; Joltreau and Sommerfeld 2019). Technical challenges arise because 16 estimating the price adjustment requires reliable data on the GHG content of products imported as well 17 as a clear understanding of the climate policies implications from the countries of imports. Application 18 of pricing tools in industry requires standardization (benchmarking) of carbon intensity assessments at 19 products, installations, enterprises, countries, regions, and the global level. The limited number of 20 existing benchmarking systems are not yet harmonized and thus not able fulfill this function 21 effectively. This limits the scope of products that can potentially be covered by CBAM type policies 22 (Bashmakov et al. 2021a) | 1931 - 193 | Impact | | |
| IPCC_AR6_WGIII_Full_Report | 15 2016). As a result, jurisdictions are increasingly considering new requirements in building codes to 16 reduce embodied emissions. This is the case of France's new building code which is shifting from a 17 thermal regulation (RT 2012) to an environmental regulation (RE 2020) to include embodied GHG 18 LCA metrics for encouraging use of low-GHG building materials (Schwarz et al. 2020; Ministère de la 19 Transition écologique et solidaire 2018). The 2018 International Green Construction Code (IGCC) 20 provides technical requirements that can be adopted by jurisdictions for encouraging low GHG building 21 construction, which also covers minimum longevity and durability of structural, building envelope, and 22 hardscape materials (Art. 1001.3.2.3) (Celadyn 2014). Low GHG Building Rating Systems, such as 23 LEEDs, are voluntary standards which include specific requirements on material resources in their 24 rating scale. Trade-offs between energy performance achievement and material used in building 25 construction needs to be further assessed and considered as low GHG building code requirements 26 develop. Local governments can also lead the way by adopting standards for construction. This is the case of the county of Marin in California which specifies maximum embodied carbon in kgCO2-eq m-3 27 and maximum ordinary Portland cement content in lbs/yd3 28 for different levels of concrete compressive 29 strength (Marin County 2021). | 1940 - 1940 | | | |
| IPCC_AR6_WGIII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 11 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 11-98 Total pages: 135 1 Energy intensive production steps may move where clean resources are most abundant and relatively 2 inexpensive (Bataille et al. 2021a; Gielen et al. 2020). For example, steel making has historically located 3 itself near iron ore and coal resources whereas in the future it may be located near iron ore and zero 4 GHG electricity or close to carbon storage sites (Fischedick et al. 2014b; Vogl et al. 2018; Bataille 5 2020a). This indicates large changes in industrial and supply chain structure, with directly associated 6 needs for employment and skills. Some sectors will grow, and some will shrink, with differing skill 7 needs. Each new workforce cohort needs the general specific skill to provide the employment that is 8 needed at each stage in the transition, implicating a need for co-ordination with policies for education 9 and retraining. | 1943 - 1944 | | | |

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| IPCC_AR6_WGIII_Full_Report | 25 12.3.1.1 Direct Air Carbon Capture and Storage (DACCS) 26 Direct air capture (DAC) is a chemical process to capture ambient CO2 from the atmosphere. Captured 27 CO2 can be stored underground (direct air capture carbon and storage, DACCS) or utilised in products 28 (direct air capture carbon and utilisation, DACCU). DACCS shares with conventional CCS the transport 29 and storage components but is distinct in its capture part. Because CO2 is a well-mixed GHG, DACCS 30 can be sited relatively flexibly, though its locational flexibility is constrained by the availability of low- 31 carbon energy and storage sites. Capturing the CO2 involves three basic steps: a) contacting the air, b) 32 capturing on a liquid or solid sorbent or a liquid solvent, c) regeneration of the solvent or the sorbent 33 (with heat, moisture and/or pressure). After capture, the CO2 stream can be stored underground or 34 utilised. The duration of storage is an important consideration; geological reservoirs or mineralisation 35 result in removal for > 1000 years. The duration of the removal through DACCU (Breyer et al. 2019) 36 varies with the lifetime of respective products (Wilcox et al. 2017; Gunnarsson et al. 2018; Bui et al. | 2023 - 2023 | | | |
| IPCC_AR6_WGIII_Full_Report | 3 Status: Enhanced weathering has been demonstrated in the laboratory and in small scale field trials 4 (TRL 3–4) but has yet to be demonstrated at scale (Beerling et al. 2018; Amann et al. 2020). The 5 chemical reactions are well understood (Gillman 1980; Gillman et al. 2001; Manning 2008), but the 6 behaviour of the crushed rocks in the field and potential co-benefits and adverse-side effects of 7 enhanced weathering require further research (Beerling et al. 2018). Small scale laboratory experiments 8 have calculated weathering rates that are orders of magnitude slower than the theoretical limit for mass 9 transfer-controlled forsterite (Renforth et al. 2015; Amann et al. 2020) and basalt dissolution (Kelland 10 et al. 2020). Uncertainty surrounding silicate mineral dissolution rates in soils, the fate of the released 11 products, the extent of legacy reserves of mining by-products that might be exploited, location and 12 availability of rock extraction sites, and the impact on ecosystems remain poorly quantified and require 13 further research to better understand feasibility (Renforth 2012; Moosdorf et al. 2014; Beerling et al. | 2027 - 202 | Impact | | |
| IPCC_AR6_WGIII_Full_Report | 41 Risks and impacts: Mining of rocks for enhanced weathering will have local impacts and carries risks 42 similar to that associated with the mining of mineral construction aggregates, with the possible 43 additional risk of greater dust generation from fine comminution and land application. In addition to 44 direct habitat destruction and increased traffic to access mining sites, there could be adverse impacts on 45 local water quality (Younger and Wolkersdorfer 2004). | 2027 - 202 | Impact | | |
| IPCC_AR6_WGIII_Full_Report | 16 Food regulations: Novel foods based on insects, microbial proteins or cellular agriculture must go 17 through authorisation processes to ensure compliance with food safety standards before they can be 18 sold to consumers. Several countries have 'novel food' regulations governing the approval of foods for 19 human consumption. For example, the European Commission, in its update of the Novel Food 20 Regulation in 2015, expanded its definition of novel food to include food from cell cultures, or that 21 produced from animals by non-traditional breeding techniques (EU 2015). | 2072 - 2072 | | INTANBILE | |

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| IPCC_AR6_WGIII_Full_Report | 36 (2021) quantified a land footprint by the infrastructure of a pilot solar plant being three times the onsite 37 land area. Sonter et al. (2020b) found significant overlap of mining areas (82% targeting materials 38 needed for renewable energy production) and biodiversity conservation sites and priorities, suggesting 39 that strategic planning is critical to address mining threats to biodiversity (See section 12.5.4) along 40 with recycling and exploration of alternative technologies that use that use abundant minerals (See 41 Chapter 11, Box Critical Minerals and The Future of Electro-Mobility and Renewables) 42 There are also situations where expanding mitigation is more or less decoupled from additional land 43 use. The use of organic consumer waste, harvest residues and processing side-streams in the agriculture 44 and forestry sectors can support significant volumes of bio-based products with relatively lower land- 45 use change risks than dedicated biomass production systems (Hanssen et al. 2019; Spinelli et al. 2019; 46 Mouratiadou et al. 2020). Such uses can provide waste management solutions while increasing the 47 mitigation achieved from the land that is already used for agricultural and forest production. Bioenergy ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Draft Chapter 12 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 12-99 Total pages: 220 1 accounts for about 90% of renewable heat used in industrial applications, mainly in industries that can 2 use their own biomass waste and residues, such as the pulp and paper industry, food industry, and 3 ethanol production plants (see Chapters 6 and 11) (IEA 2020c). Heat and electricity produced on-site 4 from side-streams but not needed for the industrial processes can be sold to other users, e.g., district 5 heating systems. Surplus waste and residues can also be used to produce solid and liquid biofuels, or be 6 used as feedstock in other industries such as the petrochemical industry (IRENA 2018; Lock and Whittle 7 2018; Thunman et al. 2018; IRENA 2019; Haus et al. 2020; Chapters 6 and 11). Electrification and 8 improved process efficiencies can reduce GHG emissions and increase the share of harvested biomass 9 that is used for production of bio-based products (Johnsson et al. 2019; Madeddu et al. 2020; Lipiäinen 10 and Vakkilainen 2021; Rahnama Mobarakeh et al. 2021; Silva et al. 2021; Chapter 11). Besides 11 integrating solar thermal panels and solar PV into buildings and other infrastructure, floating solar PV 12 panels in, e.g., hydropower dams (Ranibaran et al. 2019; Cagle et al. 2020; Haas et al. 2020; Lee et al. | 2079 - 208 | Prot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGIII_Full_Report | 7 Trade-offs between different ecosystem services, and between societal objectives including climate 8 change mitigation and adaptation, can be managed through integrated landscape approaches that aim to 9 create a mosaic of land uses, including conservation, agriculture, forestry and settlements (Freeman et 10 al. 2015; Nielsen 2016; Reed et al. 2016; Sayer et al. 2017) where each is sited with consideration of 11 land potential and socioeconomic objectives and context (Cowie et al. 2018) (limited evidence, high 12 agreement). | 2083 - 208 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGIII_Full_Report | 27 Another example of beneficial effects includes perennial grasses and woody crops planted to intercept 28 runoff and subsurface lateral flow, reducing nitrate entering groundwater and surface waterbodies (e.g 29 Woodbury et al. 2018; Femeena et al. 2018; Griffiths et al. 2019). In India, (Garg et al. 2011) found 30 desirable effects as a result of planting Jatropha on wastelands previously used for grazing (which could 31 continue in the Jatropha plantations): soil evaporation was reduced, as a larger share of the rainfall was 32 channelled to plant transpiration and groundwater recharge, and less runoff resulted in reduced soil 33 erosion and improved downstream water conditions. Thus, adverse effects can be reduced and synergies 34 achieved when plantings are sited carefully, with consideration of potential hydrological impacts (Davis 35 et al. 2013). | 2083 - 208 | Impact | | |
| IPCC_AR6_WGIII_Full_Report | 40 2021), while painting blades to increase the visibility can also reduce mortality due to collision (May et 41 al. 2020). Theoretical studies have suggested that wind turbines could lead to warmer night temperatures 42 due to atmospheric mixing (Keith et al. 2004), later confirmed through observation (Zhou et al. 2013), 43 although Vautard et al. (2014) found limited impact at scales consistent with climate policies. More 44 recent studies report mixed results; indications that the warming effect could be substantial with 45 widespread deployment Miller and Keith 2018b and conversely limited impacts on regional climate at 46 20% of US electricity from wind. (Pryor et al. 2020). | 2085 - 208 | Impact | | |

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| IPCC_AR6_WGIII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS Final Government Draft Chapter 12 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 12-105 Total pages: 220 1 Solar power 2 As for wind power, land impacts of solar power depend on the location, size and type of installation 3 (Ioannidis and Koutsoyiannis 2020). Establishment of large-scale solar farms could have positive or 4 negative environmental effects at the site of deployment, depending on the location. Solar PV and CSP 5 power installations can lock away land areas, displacing other uses (Mohan 2017). Solar PV can be 6 deployed in ways that enhance agriculture: for example, Hassanpour Adeh et al. (2018) found that 7 biomass production and water use efficiency of pasture increased under elevated solar panels. PV 8 systems under development may achieve significant power generation without diminishing agricultural 9 output (Miskin et al. 2019). Global mapping of solar panel efficiency showed that croplands, grasslands 10 and wetlands are located in regions with the greatest solar PV potential (Adeh et al. 2019). Dual-use 11 agrivoltaic systems are being developed that overcome previously recognised negative impact on crop 12 growth, mainly due to shadows (Armstrong et al. 2016; Marrou et al. 2013b,a), thus facilitating 13 synergistic co-location of solar photovoltaic power and cropping (Miskin et al. 2019; Adeh et al. 2019). | 2085 - 208 | Impact | | |
| IPCC_AR6_WGIII_Full_Report | 17 Deserts can be well-suited for solar PV and CSP farms, especially at low latitudes where global 18 horizontal irradiance is high, as there is lower competition for land and land carbon loss is minimal, 19 although remote locations may pose challenges for power distribution (Xu et al. 2016). Solar arrays can 20 reduce the albedo, particularly in desert landscapes, which can lead to local temperature increases and 21 regional impacts on wind patterns (Millstein and Menon 2011). Modelling studies suggest that large- 22 scale wind and solar farms, for example in the Sahara (Li et al. 2018), could increase rainfall through 23 reduced albedo and increased surface roughness, stimulating vegetation growth and further increasing 24 regional rainfall (Li et al. 2018) (limited evidence). Besides impacts at the site of deployment, wind 25 and solar power affect land through mining of critical minerals required by these technologies (Viebahn 26 et al. 2015; McLellan et al. 2016; Carrara et al. 2020). | 2086 - 208 | Impact | | |
| IPCC_AR6_WGIII_Full_Report | 14 Hydropower projects may impact aquatic ecology and biodiversity, necessitate the relocation of local 15 communities living within or near the reservoir or construction sites and affect downstream 16 communities (in positive or negative ways) (Barbarossa et al. 2020; Moran et al. 2018). Displacement 17 as well as resettlement schemes can have both socio-economic and environmental consequences 18 including those associated with establishment of new agricultural land (Nguyen et al. 2017; Ahsan and 19 Ahmad 2016). Dam construction may also stimulate migration into the affected region, which can lead 20 to deforestation and other negative impacts (Chen et al. 2015). Impacts can be mitigated through basin- 21 scale dam planning that considers GHG emissions along with social and ecological effects (Almeida et 22 al. 2019). Land occupation is minimal for run-of-river hydropower installations, but without storage 23 they have no resilience to drought and installations inhibit dispersal and migration of organisms (Lange 24 et al. 2018). Reservoir hydropower schemes can regulate water flows and reduce flood damage to 25 agricultural production (Amjath-Babu et al. 2019). On the other hand, severe flooding due to failure of 26 hydropower dams has caused fatalities, damage to infrastructure and loss of productive land (Lu et al. | 2087 - 208 | Prot-Adapt-Mitig-Impac | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | 16 Integrative spatial planning can integrate renewable energy with not just agriculture, but mobility and 17 housing (Hurlbert et al. 2019). Integrated planning is needed to avoid scalar pitfalls, and local and 18 regional contextualised governance solutions need to be sited within a planetary frame of reference 19 (Biermann et al. 2016). Greater planning and coordination are also needed to ensure co-benefits from 20 land-based mitigation (see Box 12.3) as well as from CDR and efforts to reduce food systems emissions. | 2088 - 208 | Prot-Adapt-Mitig- | | |

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| IPCC_AR6_WGIII_Full_Report | {12.5.3} Solar panels Land use competition {12.5.3} Integration with buildings and other infrastructure. integration with food production is being explored {12.5.2} Enhanced weathering Disturbance at sites of extraction; Ineffective in low rainfall regions {12.3.1.2} Increase crop yields and biomass production through nutrient supply and increasing pH of acid soils; synergies with biochar {12.5.3} Bio-based options that may displace existing food production A/R Land use competition, potentially leading to indirect land use change; reduced water availability; loss of biodiversity {12.5.3} Strategic siting to minimise adverse impacts on hydrology, land use, biodiversity {12.5.3} Biomass crops Land use competition, potentially leading to indirect land use change; reduced water availability; reduced soil fertility; loss of biodiversity {12.5.3} Strategic siting to minimise adverse impacts / enhance beneficial effects on land use, landscape variability, biodiversity, soil organic matter, hydrology and water quality {12.5.3} Bio-based options that can (to a varying degree) be combined with food production ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Draft Chapter 12 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 12-111 Total pages: 220 Agroforestry Competition with adjacent crops and pastures reduces yields {7.4.3.3} Shelter for stock and crops, diversification, biomass production, increases soil organic matter and soil fertility. Increased biodiversity and perennial vegetation enhance beneficial organisms; can reduce need for pesticides {7.4.3.3, 12.5.3} Soil carbon management in croplands and grasslands Increase in nitrous oxide emissions if fertiliser used to enhance crop production; Reduced cereal production through increased crop legumes and pasture phases could lead to indirect land use change {7.4.3.1, 7.4.3.6} Increasing soil organic matter improves soil health, increases crop and pasture yields, and resilience to drought, can reduce fertiliser requirement, nutrient leaching and need for land use change. | 2091 - 209 | Impact | | |
| IPCC_AR6_WGIII_Full_Report | 7 A range of examples of where mitigation measures result in cross-sectoral interactions and integration 8 is identified. The mitigation potential of electric vehicles, including plug-in hybrid hybrids, is linked to 9 the extent of decarbonisation of the electricity grid, as well as to the liquid fuel supply emissions profile 10 (Lutsey 2015). Making buildings energy positive, where excess energy is used to charge vehicles, can 11 increase the potential of electric and hybrid vehicles (Zhou et al. 2019). Advanced process control and 12 process optimisation in industry can reduce energy demand and material inputs (Section 11.3), which 13 in turn can reduce emissions linked to resource extraction and manufacturing. Reductions in coal-fired 14 power generation through replacement with renewables or nuclear power result in a reduction in coal 15 mining and its associated emissions. Increased recycling results in a reduction in emissions from 16 primary resource extraction. CCU can contribute to the transition to more renewable energy systems 17 via power-to-X technologies, which enables the production of CO2-based fuels/e-fuels and chemicals 18 using carbon dioxide and hydrogen ( Breyer et al. 2015; Anwar et al. 2020). Certain reductions in the 19 AFOLU sector are contingent on energy sector decarbonisation. Trees and green roofs planted to 20 counter urban heat islands reduce the demand for energy for air conditioning and simultaneously 21 sequester GHGs (Kim and Coseo 2018; Kuronuma et al. 2018). Recycling of organic waste avoids 22 methane generation if the waste would have been disposed of in landfill sites, can generate renewable 23 energy if treated through anaerobic digestion and can reduce requirements for synthetic fertiliser 24 production if the nutrient value is recovered (Creutzig et al. 2015). Liquid transport biofuels links to the 25 land, energy and transport sectors (Section 12.5.2.2). | 2101 - 210 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGIII_Full_Report | 35 Moreover, deep mitigation requires moving beyond existing technological responses (Mulugetta and Castán 36 Broto 2018) to policies that correspond to the realities of developing countries (Bouteligier 2013). However, 37 best practice approaches tend to be fragmented due to the requirements of different contexts, and often 38 executed as pilot projects that rarely lead to structural change (Nagorny-Koring 2019). Instead, context- 39 specific approaches that include consideration of values, cultures and governance better enable successful 40 translation of best practices (Affolderbach and Schulz 2016; Urpelainen 2018). | 2222 - 222 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGIII_Full_Report | 8 Significant variation in ideas, values and beliefs related to climate governance are detected across and within 9 regions, countries, societies, organisations, and individuals (Shwom et al. 2015; Boasson et al. 2021; Knox- 10 Hayes 2016; Wettestad and Gulbrandsen 2018) (medium evidence, medium agreement). These factors 11 provide the context for climate policymaking and include differences in countries' histories (Aamodt 2018; 12 Aamodt and Boasson 2020); the political culture and regulatory traditions in governing environmental and 13 energy issues (Tosun 2018; Aamodt 2018; Boasson et al. 2021); and even bureaucrats' educational 14 background (Rickards et al. 2014). Structural factors in a country, such as deeply held value systems, are not 15 changed rapidly, just as political systems or natural endowments, are not changed rapidly. Consequently 16 climate policy and governance is more effective if it takes into account these deep-rooted values and beliefs. | 2226 - 222 | Impact | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | 39 This is not surprising, given that courts play differing roles across varying political systems and law traditions 40 (La Porta et al. 1998). | 2230 - 2230 | | INTANBILE | |

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| IPCC_AR6_WGII_Full_Report | 8 Overall, courts have also played a more active role for climate governance in democratic political systems 9 (Peel and Osofsky 2015; Eskander et al. 2021), but recently legal reforms have also developed in other 10 countries, such as the environmental public interest law in China that allows individuals and groups to initiate 11 environmental litigation (Xie and Xu 2021; Zhao et al. 2019). Whether and to what extent differing law 12 traditions and political systems influence the role and importance of climate litigation has, however, not been 13 examined enough scientifically (Peel and Osofsky 2020; Setzer and Vanhala 2019). | 2231 - 2231 | | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 3 4 13.4.3 Media as communicative platforms for shaping climate governance 5 Media is another platform for various actors to present, interpret and shape debates around climate change 6 and its governance (Tindall et al. 2018). The media coverage of climate change has grown steadily since 7 1980's (O'Neill et al. 2015; Boykoff et al. 2019), but the level and type of coverage differs over time and 8 from country to country (Boykoff 2011; Schmidt et al. 2013; Schäfer and Schlichting 2014) (robust evidence, 9 high agreement). Media can be a useful conduit to build public support to accelerate mitigation action, but 10 may also be utilized to impede decarbonisation endeavours (Farrell 2016b; Carmichael et al. 2017; 11 Carmichael and Brulle 2018; Boykoff 2011; O'Neill et al. 2015). Different media systems in different regions 12 and countries and with unique cultural and political traditions also affect how climate change is 13 communicated (Eskjær 2013). | 2233 - 223 | Prot-Adapt-Mitig- | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 21 Popular culture images, science fictions and films of ecological catastrophe can dramatically and emotively 22 convey the dangers of climate change (Bulfin 2017). The overall accuracy of the media coverage on climate 23 change has improved from 2005 to 2019 in the United Kingdom (UK), Australia, New Zealand, Canada, and 24 the US (McAllister et al. 2021). Moreover, coverage of climate science is increasing. One study (MeCCO) 25 has tracked media coverage of climate change from over 127 sources from 59 countries in North and Latin 26 America, Europe, Middle East, Africa, Asia and Oceania (Boykoff et al. 2021). It shows the number of media 27 science stories in those sources grew steadily from 47376 per annum to 86587 per annum between 2017 and 28 2021 across print, broadcast, digital media and entertainment (Boykoff et al. 2021). | 2233 - 2233 | | | |
| IPCC_AR6_WGII_Full_Report | 31 Experiments span smart technologies (e.g., in Malmö, Sweden (Parks 2019), Eco-Art, Transformation-Labs 32 and other approaches that question the cultural basis of current energy regimes and seek reimagined or 33 reinvented futures (Guy et al. 2015; Voytenko et al. 2016; Hodson et al. 2018; Peng and Bai 2018; Culwick 34 et al. 2019; Pereira et al. 2019; Sengers et al. 2019; Castán Broto and Bulkeley 2013; Smeds and Acuto 35 2018). They may include governance experiments, from formally defined policy experiments to informal 36 initiatives that mobilise new governance concepts (Kivimaa et al. 2017a; Turnheim et al. 2018), and co- 37 design initiatives and grassroots innovations (Martiskainen 2017; Sheikh and Bhaduri 2021). These 38 initiatives often expand the scope for citizen participation. For example, Urban Living Labs foster 39 innovation, coproducing responses to existing problems of energy use, energy poverty and mobility that 40 integrate scientific and expert knowledge with local knowledge and common values (Voytenko et al. 2016; 41 Marvin et al. 2018). The European Network of Living Labs- with a global outreach- has established a model 42 of open and citizen-centric innovation for policy making. The proliferation of Climate Assemblies at the 43 national and sub-national level further emphasises the increasing role that citizens can play in both innovating 44 and planning for carbon mitigation (Sandover et al. 2021). | 2237 - 223 | Prot-Adapt-Mitig- | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 32 Energy efficiency labelling is in widespread use, including for buildings, and for end users products including 33 cars and appliances. Carbon labelling is used for example for food (Camilleri et al. 2019) and tourism 34 (Gössling and Buckley 2016). Information measures also include specific information systems such as smart 35 electricity meters (Zangheri et al. 2019). Chapters 5 and 9 provide detail. | 2253 - 2253 | | | |

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| IPCC_AR6_WGIII_Full_Report | 11 In practice, integration has to occur in the context of an already existing policy structure, which suggests the 12 need for finding windows of opportunity to bring about integration, which can be created by international 13 events, alignments with domestic institutional procedures, and openings created by policy entrepreneurs 14 (Garcia Hernandez and Bolwig 2020). Integration also has to occur in the context of existing organisational 15 routines and cultures, which can pose a barrier to integration (Uittenbroek 2016). Experience from the EU 16 suggests that disagreements at the level of policy instruments are amenable to resolution by deliberation, 17 while normative disagreements at the level of objectives require a hierarchical decision structure (Skovgaard 18 2018). As this discussion suggests, the challenge of integration operates in two dimensions: horizontal -- 19 between sectoral authorities such as ministries or policy domains such as forestry -- or vertical -- either 20 between constitutional levels of power or within the internal mandates and interactions of a sector (Howlett 21 and del Rio 2015; Di Gregorio et al. 2017). There are also important temporal dimensions to policy goals, as 22 policy and benchmarks have to address not just immediate success but also indications of future 23 transformation (Dupont and Oberthür 2012; Dupont 2015). | 2264 - 2264 | | | |
| IPCC_AR6_WGIII_Full_Report | Co-benefits generated by climate actions at cities: heat stress reduction; water scarcity, stormwater and flood management; air quality improvement, human health and well being, aesthetic/ amenity, recreation / tourism, environmental justice, real estate value, food production, green jobs opportunities. | 2273 - 2273 | | | |
| IPCC_AR6_WGIII_Full_Report | • Carbon storage and sequestration • Reduced energy consumption Adaptation benefits: flood management, heat stress reduction individually, or jointly, coastal protection, water scarcity management, groundwater resources, ecosystem resilience improvement, air quality, water supply, flood control, water quality improvement, groundwater recharge. Social co-benefits: aesthetic, recreation, environmental education, improved human health/wellbeing, social cohesion, and poverty reduction. Policy examples: National building code guidelines, flood safety standards, local land-use plans, local building codes, integrated water management for flood control, (Atchison 2019; Conger and Chang 2019; Schoonees et al. 2019; De la Sota et al. 2019; Choi et al. 2021; Zwierzchowska et al. 2019) REDD+ Strategies; An incentive for developing countries to increase carbon sinks, to protect their forest resources and coastal wetlands. Mostly are national strategies led by the state with contribution of international donors. | 2273 - 227 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGIII_Full_Report | 17 Justice principles are rarely incorporated in climate change framing and action (Sovacool and Dworkin 2015; 18 Genus and Theobald 2016; Heikkinen et al. 2019; Romero-Lankao and Gnatz 2019). Yet, equity is salient to 19 mitigation debates, because climate change mitigation policies can have also negative impacts (Brugnach et 20 al. 2017; Ramos-Castillo et al. 2017; Klinsky 2018), exacerbated by poverty, inequality and corruption 21 (Markkanen and Anger-Kraavi 2019; Reckien et al. 2018). The siting of facilities and infrastructure that 22 advance decarbonisation (such as public transit infrastructure, renewable energy facilities etc.) may have 23 implications for environmental justice. Integrated attention to justice in climate, environment and energy, as 24 well as involvement of host communities in siting assessments and decision-making processes, can help to 25 avoid such conflict (McCord et al. 2020; Hughes and Hoffmann 2020). As a result, successful policy 26 integration goes beyond optimizing public management routines, and must resolve key trade-offs between 27 actors and objectives (Meadowcroft 2009; Nordbeck and Steurer 2016). | 2276 - 227 | 'rot-Adapt-Mitig-Impac | | |
| IPCC_AR6_WGIII_Full_Report | 13 Becken (2019) argues that only systemic changes at a large scale will be sufficient to break or disrupt existing 14 arrangements and routines in the tourism industry 15 Others argue for thinking about mitigation in even wider ways. O'Brien (2018) posits that sector-focused, or 16 a silo approach, to mitigation may need to give way to decisions and policies which reach across sectoral, 17 geographic and political boundaries and involve a broad set of interrelated processes – practical, political 18 and personal. Gillard et al. (Gillard et al. 2016) argue that a response to climate change has to move beyond 19 incremental responses, aiming instead for a society wide transformation which goes beyond a system 20 perspective to include learning from social theory; while Eyre et al. (2018) argue that moving beyond 21 incremental emissions reductions will require expanding the focus of efforts beyond the technical to include 22 people, and their behaviour and attitudes. Stoddard et al. (2021) argue that 'more sustainable and just futures 23 require a radical reconfiguration of long-run socio-cultural and political economic norms and institutions'. | 2280 - 228 | Prot-Adapt-Mitig- | INTANBILE | |

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| IPCC_AR6_WGIII_Full_Report | Potential (e.g., US) withdrawal further reduces these chances considerably 1 2 In a dynamic context, the literature on climate clubs highlights the co-called ‘building blocks’ approach 3 (Stewart et al. 2013a,b, 2017). This is a bottom-up strategy designed to create an array of smaller-scale, 4 specialised initiatives for transnational cooperation in particular sectors and/or geographic areas with a 5 wide range of participants. As part of this literature, Potoski and Prakash (2013) provide a conceptual 6 overview of voluntary environmental clubs, showing that many climate clubs do not require demanding 7 obligations for membership and that a substantial segment thereof are mostly informational (Weischer 8 et al. 2012; Andresen 2014). Also crafted onto the building blocks approach, Potoski (2017) 9 demonstrates the theoretical potential for green certification and green technology clubs. Green (2017) 10 further highlights the potential of “pseudo-clubs” with fluid membership and limited member benefits 11 to promote the diffusion and uptake of mitigation standards. Falkner et al. (2021) suggest a typology of 12 normative, bargaining, and transformational clubs. Before the adoption of the Paris Agreement, some 13 literature suggested that the emergence of climate clubs in parallel to the multilateral climate regime 14 would lead to “forum shopping”, with states choosing the governance arrangement that best suits their 15 interests (McGee and Taplin 2006; van Asselt 2007; Biermann et al. 2009; Oh and Matsuoka 2017). | 2372 - 237 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGIII_Full_Report | 17 The Kyoto Protocol specifies GHG emissions reduction targets for the 2008-2012 commitment period 18 for countries listed in its Annex B (which broadly corresponds to Annex I to the UNFCCC) (UNFCCC 19 1997, Art. 3 and Annex B). The Kyoto Protocol entered into force in 2005. Shortly thereafter, states 20 began negotiating a second commitment period under the Protocol for Annex B parties, as well as 21 initiated a process under the UNFCCC to consider long-term cooperation among all parties. | 2375 - 2375 | | | |
| IPCC_AR6_WGIII_Full_Report | 8 Figure 14.1 illustrates graphically the key features of the Paris Agreement. The Paris Agreement is 9 based on a set of binding procedural obligations requiring parties to ‘prepare, communicate, and 10 maintain’ ‘nationally determined contributions’ (NDCs) (UNFCCC 2015a, Art. 4.2) every five years 11 (UNFCCC 2015a, Art. 4.9). These obligations are complemented by: (1) an ‘ambition cycle’ that 12 expects parties, informed by five-yearly global stocktakes (Art 14), to submit successive NDCs 13 representing a progression on their previous NDCs (UNFCCC 2015a; Bodansky et al. 2017b), and (2) 14 an ‘enhanced transparency framework’ that places extensive informational demands on parties, tailored 15 to capacities, and establishes review processes to enable tracking of progress towards achievement of 16 NDCs (Oberthür and Bodle 2016). In contrast to the Kyoto Protocol with its internationally inscribed 17 targets and timetable for emissions reduction for developed countries, the Paris Agreement contains 18 nationally determined contributions embedded in an international system of transparency and 19 accountability for all countries (Doelle 2016; Maljean-Dubois and Wemaëre 2016) accompanied by a 20 shared global goal, in particular in relation to a temperature limit. | 2381 - 2381 | | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGIII_Full_Report | 21 14.3.2.1 Context and purpose 22 The preamble of the Paris Agreement lists several factors that provide the interpretative context for the 23 Agreement (Carazo 2017; Bodansky et al. 2017b), including a reference to human rights. The human 24 rights implications of climate impacts garnered particular attention in the lead up to Paris (Duyck 2015; 25 Mayer 2016b). In particular, the Human Rights Council, its special procedures mechanisms, and the 26 Office of the High Commissioner for Human Rights, through a series of resolutions, reports, and 27 activities, advocated a rights-based approach to climate impacts, and sought to integrate this approach 28 in the climate change regime. The Paris Agreement's preambular recital on human rights recommends 29 that parties, 'when taking action to address human rights', take into account 'their respective obligations 30 on human rights' (UNFCCC 2015a, preambular recital 14), a first for an environmental treaty (Knox 31 2016). The 'respective obligations' referred to in the Paris Agreement could potentially include those ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 14 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 14-21 Total pages: 155 1 relating to the right to life (UNGA 1948, Art. 3, 1966, Art. 6), right to health (UNGA 1966b, Art. 12), 2 right to development, right to an adequate standard of living, including the right to food (UNGA 1966b, 3 Art. 11), which has been read to include the right to water and sanitation (CESCR 2002, 2010), the right 4 to housing (CESCR 1991), and the right to self-determination, including as applied in the context of 5 indigenous peoples (UNGA 1966a,b, Art. 1). In addition, climate impacts contribute to displacement 6 and migration (Mayer and Crépeau 2016; McAdam 2016), and have disproportionate effects on women 7 (Pearse 2017). There are differing views on the value and operational impact of the human rights recital 8 in the Paris Agreement (Adelman 2018; Boyle 2018; Duyck et al. 2018; Rajamani 2018; Savaresi 2018; 9 Knox 2019). Notwithstanding proposals from some parties and stakeholders to mainstream and 10 operationalise human rights in the climate regime post-Paris (Duyck et al. 2018), and references to 11 human rights in COP decisions, the 2018 Paris Rulebook contains limited and guarded references to 12 human rights (Duyck 2019; Rajamani 2019) (see Section 14.5.1.2). In addition to the reference to human 13 rights, the preamble also notes the importance of 'ensuring the integrity of all ecosystems, including 14 oceans and the protection of biodiversity' which provides opportunities for integrating and 15 mainstreaming other environmental protections. | 2381 - 238 | 'rot-Adapt-Mitig-Impac | | INDG |
| IPCC_AR6_WGIII_Full_Report | 16 The overall purpose of international cooperation through the Paris Agreement is to enhance the 17 implementation of the UNFCCC, including its objective of stabilising atmospheric GHG concentrations 18 'at a level that would prevent dangerous anthropogenic interference with the climate system' (UNFCCC 19 1992, Art. 2). The Paris Agreement aims to strengthen the global response to the threat of climate 20 change, in the context of sustainable development and efforts to eradicate poverty, by inter alia 21 '[h]olding the increase in the global average temperature to well below 2°C above pre-industrial levels 22 and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels' (UNFCCC 23 2015a, Art. 2(1)(a)). There is an ongoing structured expert dialogue under the UNFCCC in the context 24 of the second periodic review of the long-term global goal (the first was held between 2013-2015) aimed 25 at enhancing understanding of the long-term global goal, pathways to achieving it, and assessing the 26 aggregate effect of steps taken by parties to achieve the goal. | 2382 - 238 | Impact | | |
| IPCC_AR6_WGIII_Full_Report | 36 As the risks of adverse climate impacts, even with a 'well below' 2°C increase, are substantial, the 37 purpose of the Paris Agreement extends to increasing adaptive capacity and fostering climate resilience 38 (UNFCCC 2015a, Art. 2(1)(b)), as well as redirecting investment and finance flows (UNFCCC 2015a, 39 Art (2)(1)(c); Thorgeirsson 2017). The finance and adaptation goals are not quantified in the Paris 40 Agreement itself but the temperature goal and the pathways they generate may, some argue, enable a 41 quantitative assessment of the resources necessary to reach these goals, and the nature of the impacts 42 requiring adaptation (Rajamani and Werksman 2018). The decision accompanying the Paris Agreement 43 resolves to set a new collective quantified finance goal prior to 2025 (not explicitly limited to developed countries), with USD100 billion yr-1 44 as a floor (UNFCCC 2016a, para. 53; Bodansky et al. 2017b). | 2382 - 238 | 'rot-Adapt-Mitig-Impac | | |

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| Report Title (Year) | Quotation Content | Page(s) | Prot-Adapt-Mitig-Impact* | Intangible** | Indigenous*** |
|---|---|---|---|---|---|
| IPCC_AR6_WGIII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS Final Government Distribution Chapter 14 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 14-22 Total pages: 155 1 The Paris Agreement's purpose is accompanied by an expectation that the Agreement 'will be' 2 implemented to 'reflect equity and the principle of common but differentiated responsibilities and 3 respective capabilities (CBDRRC), in the light of different national circumstances' (UNFCCC 2015a, 4 Art. 2.2). This provision generates an expectation that parties will implement the agreement to reflect 5 CBDRRC, and is not an obligation to do so (Rajamani 2016a). Further, the inclusion of the term 'in 6 light of different national circumstances' introduces a dynamic element into the interpretation of the 7 CBDRRC principle. As national circumstances evolve, the application of the principle will also evolve 8 (Rajamani 2016a). This change in the articulation of the CBDRRC principle is reflected in the shifts in 9 the nature and extent of differentiation in the climate change regime (Maljean-Dubois 2016; Rajamani 10 2016a; Voigt and Ferreira 2016a), including through a shift towards 'procedurally-oriented 11 differentiation' for developing countries (Huggins and Karim 2016). | 2382 - 2383 | | | |
| IPCC_AR6_WGIII_Full_Report | 12 Although NDCs are developed by individual state parties, the Paris Agreement requires that these are 13 undertaken by parties 'with a view' to achieving the Agreement's purpose and collectively 'represent a 14 progression over time' (UNFCCC 2015a, Art. 3). The Paris Agreement also encourages parties to align 15 the ambition of their NDCs with the temperature goal through the Agreement's 'ambition cycle', thus 16 imparting operational relevance to the temperature goal (Rajamani and Werksman 2018). | 2383 - 2383 | | | |
| IPCC_AR6_WGIII_Full_Report | 18 14.3.2.2 NDCs, progression and ambition 19 Each party to the Paris Agreement has a procedural obligation to 'prepare, communicate and maintain' 20 successive NDCs 'that it intends to achieve.' Parties have a further procedural obligation to 'pursue 21 domestic mitigation measures' (UNFCCC 2015a, Art. 4.2). These procedural obligations are coupled 22 with an obligation of conduct to make best efforts to achieve the objectives of NDCs (Rajamani 2016a; 23 Mayer 2018b). Many states have adopted climate policies and laws, discussed in Chapter 13, and 24 captured in databases (LSE 2020). | 2384 - 238 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGIII_Full_Report | 25 The framing and content of NDCs is thus largely left up to parties, although certain normative 26 expectations apply. These include developed country leadership through these parties undertaking 27 economy-wide absolute emissions reduction targets (UNFCCC 2015a, Art. 4.4), as well as 28 'progression' and 'highest possible ambition' reflecting 'common but differentiated responsibilities and 29 respective capabilities in light of different national circumstances' (Art 4.3). There is 'a firm 30 expectation' that for every five-year cycle a party puts forward a new or updated NDC that is 'more 31 ambitious than their last' (Rajamani 2016a). While what represents a party's highest possible ambition 32 and progression is not prescribed by the Agreement or elaborated in the Paris Rulebook (Rajamani and 33 Bodansky 2019), these obligations could be read to imply a due diligence standard (Voigt and Ferreira 34 2016b). | 2384 - 2384 | | | |
| IPCC_AR6_WGIII_Full_Report | 35 In communicating their NDCs every five years (UNFCCC 2015a, Art. 4.9), all parties have an 36 obligation to 'provide the information necessary for clarity, transparency and understanding' (UNFCCC 37 2015a, Art. 4.8). These requirements are further elaborated in the Paris Rulebook (Doelle 2019; 38 UNFCCC 2019b). This includes requirements — for parties' second and subsequent NDCs — to 39 provide quantifiable information on the reference point e.g. base year, reference indicators and target 40 relative to the reference indicator (UNFCCC 2019b, Annex I, para 1). It also requires parties to provide 41 information on how they consider their contribution 'fair and ambitious in light of different national 42 circumstances', and how they address the normative expectations of developed country leadership, 43 progression and highest possible ambition (UNFCCC 2019b, Annex I, para 6). However, parties are 44 required to provide the enumerated information only 'as applicable' to their NDC (UNFCCC 2019b, 45 Annex I, para 7). This allows parties to determine the informational requirements placed on them 46 through their choice of NDC. In respect of parties' first NDCs or NDCs updated by 2020, such 47 quantifiable information 'may' be included, 'as appropriate', signalling a softer requirement, although 48 parties are 'strongly encouraged' to provide this information (UNFCCC 2019b, Annex I, para 9). | 2384 - 2384 | | | |
| IPCC_AR6_WGIII_Full_Report | 3 4 14.3.2.3 NDCs, fairness and equity 5 The Paris Agreement encourages Parties, while submitting their NDCs, to explain how these are 'fair 6 and ambitious' (UNFCCC 2015a, Art. 4.8 read with UNFCCC 2016a, para. 27). The Rulebook obliges 7 Parties to provide information on 'fairness considerations, including reflecting on equity' as applicable 8 to their NDC (Rajamani and Bodansky 2019; UNFCCC 2019b paras 7a and 9, Annex, paras 6(a) and 9 (b)). Although equity within nations and between communities is also important, much of the literature 10 on fairness and equity in the context of NDCs focuses on equity between nations. | 2387 - 2387 | | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGIII_Full_Report | 25 14.3.2.4 Transparency and accountability 26 Although NDCs reflect a 'bottom-up', self-differentiated approach to climate mitigation actions, the 27 Paris Agreement couples this to an international transparency framework designed, among other things, 28 to track progress in implementing and achieving mitigation contributions (UNFCCC 2015a, Art. 13). | 2388 - 238 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGIII_Full_Report | 29 This transparency framework builds on the processes that already exist under the UNFCCC. The 30 transparency framework under the Paris Agreement s applicable to all Parties, although with flexibilities 31 for developing country Parties that need it in light of their capacities (Mayer 2019). Each Party is 32 required to submit a national inventory report, as well as 'the information necessary to track progress 33 in implementing and achieving' its NDC, (UNFCCC 2015a, Art. 13.7) biennially (UNFCCC 2016a, 34 para. 90). The Paris Rulebook requires all Parties to submit their national inventory reports using the 35 2006 IPCC Guidelines (UNFCCC 2019b, Annex, para. 20). | 2388 - 2388 | | | |
| IPCC_AR6_WGIII_Full_Report | 36 In relation to the provision of information necessary to track progress towards implementation and 37 achievement of NDCs, the Paris Rulebook allows each party to choose its own qualitative or 38 quantitative indicators (UNFCCC 2019k, Annex, para 65), a significant concession to national 39 sovereignty (Rajamani and Bodansky 2019). The Rulebook phases in common reporting requirements 40 for developed and developing countries (except LDCs and SIDS) at the latest by 2024 (UNFCCC 41 2019k, para. 3), but offers flexibilities in 'scope, frequency, and level of detail of reporting, and in the 42 scope of the review' for those developing countries that need it in light of their capacities (UNFCCC 43 2019k, Annex, para. 5). Some differentiation also remains for information on support provided to 44 developing countries (Winkler et al. 2017), with developed country parties required to report such 45 information biennially, while others are only 'encouraged' to do so (UNFCCC 2015a, Art. 9.7). | 2388 - 2388 | | | |
| IPCC_AR6_WGIII_Full_Report | 18 14.3.2.5 Global stocktake 19 The Paris Agreement's transparency framework is complemented by the global stocktake, which will 20 take place every five years (starting in 2023) and assess the collective progress towards achieving the 21 Agreement's purpose and long-term goals (UNFCCC 2015a, Art. 14). The scope of the global stocktake 22 is comprehensive – covering mitigation, adaptation and means of implementation and support – and the 23 process is to be facilitative and consultative. The Paris Rulebook outlines the scope of the global 24 stocktake to include social and economic consequences and impacts of response measures, and loss and 25 damage associated with the adverse effects of climate change (UNFCCC 2019f, paras. 8-10). | 2389 - 238 | 'rot-Adapt-Mitig-Impac | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | 36 The global stocktake is seen as crucial to encouraging parties to increase the ambition of their NDCs 37 (Huang 2018; Hermwille et al. 2019; Milkoreit and Haapala 2019) as its outcome 'shall inform Parties 38 in updating and enhancing, in a nationally determined manner, their actions and support' (Art 14.3) 39 (Rajamani 2016a; Friedrich 2017; Zahar 2019). The Rulebook provides for the stocktake to draw on a 40 wide variety of inputs sourced from a full range of actors, including 'non-Party stakeholders' (UNFCCC 41 2019f, para. 37). However, the Rulebook specifies that the global stocktake will be 'a Party-driven 42 process' (UNFCCC 2019f, para. 10), will not have an 'individual Party focus', and will include only 43 'non-policy prescriptive consideration of collective progress' (UNFCCC 2019f, para. 14). | 2389 - 2389 | | | |
| IPCC_AR6_WGIII_Full_Report | 45 14.3.2.8 Finance flows 46 Finance is the first of three means of support specified under the Paris Agreement to accomplish its 47 objectives relating to mitigation (and adaptation) (UNFCCC 2015a, Art. 14.1). This sub-section 48 discusses the provision made in the Paris Agreement for international cooperation on finance. Section ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 14 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 14-31 Total pages: 155 1 14.4.1 below considers broader cooperative efforts on public and private finance flows for climate 2 mitigation, including by multilateral development banks and through instruments such as green bonds. | 2391 - 239 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGIII_Full_Report | 3 As highlighted above, the objective of the Paris Agreement includes the goal of '[m]aking finance flows 4 consistent with a pathway towards low greenhouse gas emissions and climate-resilient development' 5 (UNFCCC 2015a, Art 2.1(c)). Alignment of financial flows, and in some cases provision of finance 6 will be critical to the achievement of many parties' NDCs, particularly those that are framed in 7 conditional terms (Zhang and Pan 2016; Kissinger et al. 2019) (see further Chapter 15 on investment 8 and finance). | 2392 - 2392 | | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGIII_Full_Report | 27 Much of the current literature on climate finance and the Paris Agreement focuses on the obligations of 28 developed countries to provide climate finance to assist the implementation of mitigation and adaptation 29 actions by developing countries. The principal provision on finance in the Paris Agreement is the 30 binding obligation on developed country parties to provide financial resources to assist developing 31 country parties (UNFCCC 2015a, Art 9.1). This provision applies to both mitigation and adaptation and 32 is in continuation of existing developed country parties' obligations under the UNFCCC. This signals 33 that the Paris Agreement finance requirements must be interpreted in light of the UNFCCC (Yamineva 34 2016). The novelty introduced by the Paris Agreement is a further expansion in the potential pool of 35 donor countries as Article 9.2 encourages 'other parties' to provide or continue to provide such support 36 on a voluntary basis. However, 'as part of the global effort, developed countries should continue to take 37 the lead in mobilising climate finance', with a 'significant role' for public funds, and an expectation 38 that such mobilisation of finance 'should represent a progression beyond previous efforts' Beyond this 39 there are no new recognised promises (Ciplet et al. 2018). In the Paris Agreement parties formalized 40 the continuation of the existing collective mobilization goal to raise 100 billion a year through 2025 in 41 the context of meaningful mitigation actions and transparency on implementation. The Paris Agreement 42 decision also provided for the CMA by 2025 to set a new collective quantified goal from a floor of USD100 billion yr- 43 , taking into account the needs and priorities of developing countries (UNFCCC 44 2016a, para. 53). This new collective goal on finance is not explicitly limited to developed countries 45 and could therefore encompass finance flows from developing countries' donors (Bodansky et al. | 2392 - 239 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGIII_Full_Report | 33 14.3.2.9 Technology development and transfer 34 Technology development and transfer is the second of three 'means of implementation and support' 35 specified under the Paris Agreement to accomplish its objectives relating to mitigation (and adaptation) 36 (UNFCCC 2015a, Art. 14.1). This sub-section discusses the provision made in the Paris Agreement for 37 international cooperation on technology development and transfer. Section 14.4.2 below considers 38 broader cooperative efforts on technology development and transfer under the UNFCCC. Both sections 39 complement the discussion in Chapter 16.6 on the role of international cooperation in fostering 40 transformative change. | 2393 - 239 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGIII_Full_Report | 6 Article 10 of the Paris Agreement articulates a shared 'long-term vision on the importance of fully 7 realising technology development and transfer in order to improve resilience to climate change and to 8 reduce greenhouse gas emissions' (UNFCCC, 2015, Art. 10.1). All parties are required 'to strengthen 9 cooperative action on technology development and transfer' (UNFCCC, 2015, Art. 10.2). In addition, 10 support, including financial support, 'shall be provided' to developing country parties for the 11 implementation of Article 10, 'including for strengthening cooperative action on technology 12 development and transfer at different stages of the technology cycle, with a view to achieving a balance 13 between support for mitigation and adaptation' (UNFCCC, 2015, Art. 10.6). Available information on 14 efforts related to support on technology development and transfer for developing country parties is also 15 one of the matters to be taken into account in the global stocktake (UNFCCC, 2015, Art. 10.6) (see 16 Section 14.3.2.5 above). | 2394 - 239 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGIII_Full_Report | 17 The Paris Agreement emphasises that efforts to accelerate, encourage and enable innovation are 'critical 18 for an effective long-term global response to climate change and promoting economic growth and 19 sustainable development' and urges that they be supported, as appropriate, by the Technology 20 Mechanism and Financial Mechanism of the UNFCCC (UNFCCC, 2015, Art. 10.5). This support 21 should be directed to developing country parties 'for collaborative approaches to research and 22 development, and facilitating access to technology, in particular for early stages of the technology cycle' 23 (UNFCCC, 2015, Art. 10.5). Inadequate support for R&D, particularly in developing countries, has 24 been identified in previous studies of technology interventions by international institutions as a key 25 technology innovation gap that might be addressed by the Technology Mechanism (Coninck and Puig 26 2015). | 2394 - 239 | Impact | | |

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| IPCC_AR6_WGII_Full_Report | 27 To support parties' cooperative action, the Technology Mechanism, established in 2010 under the 28 UNFCCC (see further Section 14.4.2 below), will serve the Paris Agreement, subject to guidance of a 29 new 'technology framework' (UNFCCC, 2015, Art. 10.4). The latter was strongly advocated by the 30 African group in the negotiations for the Paris Agreement (Oh 2020a), and was adopted in 2018 as part 31 of the Paris Rulebook, with implementation entrusted to the component bodies of the Technology 32 Mechanism. The guiding principles of the framework are coherence, inclusiveness, a results-oriented 33 approach, a transformational approach and transparency. Its 'key themes' include innovation, 34 implementation, enabling environment and capacity-building, collaboration and stakeholder 35 engagement, and support (UNFCCC 2019e, Annex). A number of 'actions and activities' are elaborated 36 for each thematic area. These include: enhancing engagement and collaboration with relevant 37 stakeholders, including local communities and authorities, national planners, the private sector and civil 38 society organisations, in the planning and implementation of Technology Mechanism activities; 39 facilitating parties undertaking, updating and implementing technology needs assessments (TNAs) and 40 aligning these with NDCs; and enhancing the collaboration of the Technology Mechanism with the 41 Financial Mechanism for enhanced support for technology development and transfer. As regards TNAs, 42 while some developing countries have already used the results of their TNA process in NDC 43 development, other countries might benefit from following the TNA process, including its stakeholder 44 involvement, and multi-criteria decision analysis methodology, to strengthen their NDCs (Hofman and 45 van der Gaast 2019). | 2394 - 2394 | | | |
| IPCC_AR6_WGII_Full_Report | 46 14.3.2.10Capacity-building 47 Together with finance, and technology development and transfer, capacity-building is the third of 'the 48 means of implementation and support' specified under the Paris Agreement (see UNFCCC 2015a, Art. | 2394 - 2394 | | | |
| IPCC_AR6_WGII_Full_Report | 22 The Paris Agreement urges all parties to cooperate to enhance the capacity of developing countries to 23 implement the Agreement (UNFCCC 2015a, Art. 11.3), with a particular focus on LDCs and SIDS 24 (UNFCCC 2015a, Art. 11.1). Developed country parties are specifically urged to enhance support for 25 capacity-building actions in developing country Parties (UNFCCC 2015a, Art. 11.3). Article 12 of the 26 Paris Agreement addresses cooperative measures to enhance climate change education, training, public 27 awareness, public participation and public access to information, which can also be seen as elements of 28 capacity-building (Khan et al. 2020). Under the Paris Rulebook, efforts related to the implementation 29 of Article 12 are referred to as 'Action for Climate Empowerment' and parties are invited to develop 30 and implement national strategies on this topic, taking into account their national circumstances 31 (UNFCCC 2019i, para. 6). Actions to enhance climate change education, training, public awareness, 32 public participation, public access to information, and regional and international cooperation may also 33 be taken into account by parties in the global stocktake process under Article 14 of the Paris Agreement 34 (UNFCCC 2019i, para. 9). | 2395 - 2395 | | | |
| IPCC_AR6_WGII_Full_Report | 35 Under the Paris Agreement, capacity-building can take a range of forms, including: facilitating 36 technology development, dissemination and deployment; access to climate finance; education, training 37 and public awareness; and the transparent, timely and accurate communication of information 38 (UNFCCC 2015a, Art. 11.1; see also 14.3.2.4 on 'Transparency' above). Principles guiding capacity- 39 building support are that it should be: country-driven; based on and responsive to national needs; 40 fostering country ownership of parties at multiple levels; guided by lessons learned; and an effective, 41 iterative process that is participatory, cross-cutting and gender-responsive (UNFCCC 2015a, Art. 11.2). | 2395 - 239 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 42 Parties undertaking capacity-building for developing country parties must 'regularly communicate on 43 these actions or measures.' Developing countries parties have a soft requirement ('should') to 44 communicate progress made on implementing capacity-building plans, policies, actions or measures to 45 implement the Paris Agreement (UNFCCC 2015a, Art. 11.4). | 2395 - 2395 | | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGIII_Full_Report | 9 14.4.1 Finance 10 International cooperation on climate finance is underpinned by various articles of the UNFCCC 11 including Articles 4.3, 4.4, 4.5, 4.7 and 11.5 (UNFCCC 1992). This was further amplified through the 12 commitment by developed countries in the Copenhagen Accord and the Cancun Agreements to mobilise jointly through various sources USD100 billion yr-1 13 by 2020 to meet the needs of the developing 14 countries (UNFCCC 2010b). This commitment was made in the context of meaningful mitigation action 15 and transparency of implementation. As mentioned earlier in Section 14.3.2.8, in the Paris Agreement 16 the binding obligation on developed country parties to provide financial resources to assist developing 17 country parties applies to both mitigation and adaptation (UNFCCC 2015a, Art. 9.1). In 2019, climate 18 finance provided and mobilised by developed countries was in the order of USD79.6 billion, coming 19 from different channels including bilateral and multilateral channels, and also through mobilisation of 20 the private sector attributable to these channels (OECD 2021). A majority (two-thirds) of these flows 21 targeted mitigation action exclusively (see also Chapter 15). These estimates, however, have been 22 criticised on various grounds, including that they are an overestimate and do not represent climate 23 specific net assistance only; that in grant equivalence terms the order of magnitude is lower; and the 24 questionable extent of transparency of information on mobilised private finance, as well as the direction 25 of these flows (Carty et al. 2020). On balance, such assessments need to be viewed in the context of the 26 original commitment, the source of the data and the evolving guidance, and modalities and procedures 27 from the UNFCCC processes. As mentioned in Chapter 15, the measurement of climate finance flows 28 continues to face definitional, coverage and reliability issues despite progress made by various data 29 providers and collators (see section 15.3.2 in Chapter 15). | 2407 - 240 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGIII_Full_Report | 36 However, there are areas in which international cooperation can be strengthened. Both the Paris 37 Agreement and the 2030 Agenda for Sustainable Development call for more creative forms of 38 international cooperation in science that help bridge the science and policy interface, and provide 39 learning processes and places to deliberate on possible policy pathways across disciplines on a more 40 sustainable and long-lasting basis. Scientific assessments, such as the IPCC and IPBES offer this 41 possibility, but processes need to be enriched for this to happen more effectively (Kowarsch et al. 2016) 42 A particular locus for international cooperation on technology development and innovation is found 43 within institutions and mechanisms of the UN climate regime. The UNFCCC, in Article 4.1(c), calls on 44 'all parties' to 'promote and cooperate in the development, application and diffusion, including transfer, 45 of technologies, practices and processes that control, reduce or prevent anthropogenic emissions of 46 greenhouse gases' and places responsibility on developed country parties to 'take all practicable steps 47 to promote, facilitate and finance, as appropriate, the transfer of, or access to environmentally sound 48 technologies and know-how to other parties, particularly developing country parties, to enable them to ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 14 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 14-52 Total pages: 155 1 implement the provisions of the Convention' (UNFCCC 1992, Art. 4.5). The issue of technology 2 development and transfer has continued to receive much attention in the international climate policy 3 domain since its initial inclusion in the UNFCCC in 1992 – albeit often overshadowed by dominant 4 discourses around market-based mechanisms – and its role in reducing GHG emissions and adapting to 5 the consequences of climate change 'is seen as becoming ever more critical' (de Coninck and Sagar 6 2015a). Milestones in the development of international cooperation on climate technologies under the 7 UNFCCC have included: (1) the development of a technology transfer framework and establishment of 8 the Expert Group on Technology Transfer (EGTT) under the Subsidiary Body for Scientific and 9 Technological Advice (SBSTA) in 2001; (2) recommendations for enhancing the technology transfer 10 framework put forward at the Bali Conference of the Parties in 2007 and creation of the Poznan strategic 11 program on technology transfer under the Global Environmental Facility (GEF); and (3) the 12 establishment of the Technology Mechanism by the Conference of the Parties in 2010 as part of the 13 Cancun Agreements (UNFCCC 2010b). The Technology Mechanism is presently the principal avenue 14 within the UNFCCC for facilitating cooperation on the development and transfer of climate 15 technologies to developing countries (UNFCCC 2015b). As discussed in Section 14.3.2.9 above, the 16 Paris Agreement tasks the Technology Mechanism also to serve the Paris Agreement (UNFCCC 2015b, 17 Art. 10.3). | 2412 - 241 | 'rot-Adapt-Mitig-Impac | | |

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|---|---|---|---|---|---|
| IPCC_AR6_WGIII_Full_Report | 27 28 14.4.3 Capacity Building 29 International climate cooperation has long focused on supporting developing countries in building 30 capacity to implement climate mitigation actions. While there is no universally agreed definition of 31 capacity-building and the UNFCCC does not define the term (Khan et al. 2020), elements of capacity- 32 building can be discerned from the Convention's provisions on education and training programmes 33 (UNFCCC 1992, Art. 6), as well as the reference in Article 9(2)(d) of the UNFCCC to the Subsidiary 34 Body for Scientific and Technological Advice (SBSTA) providing support for 'endogenous capacity- 35 building in developing countries.' 36 Capacity-building is generally conceived as taking place at three levels: individual (focused on 37 knowledge, skills and training), organisational/institutional (focusing on organisational performance 38 and institutional cooperation) and systemic (creating enabling environments through regulatory and 39 economic policies (Khan et al. 2020; UNFCCC 2021b). In its annual synthesis report for 2018, the 40 UNFCCC secretariat compiled information submitted by parties on the implementation of capacity- 41 building in developing countries, highlighting cooperative and regional activities on NDCs, including 42 projects to build capacity for implementation, workshops related to transparency under the Paris 43 Agreement and collaboration to provide coaching and training (UNFCCC 2019h). A number of 44 developing country Parties also highlighted their contributions to South–South cooperation (discussed 45 further in Section 14.5.1.4 below), and identified capacity-building projects undertaken with others (e.g. | 2414 - 241 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGIII_Full_Report | 34 More recently, the Lowering Emissions by Accelerating Forest Finance (LEAF) Coalition was 35 established, consisting of the governments of Norway, the UK, and the US and initially nine companies 36 in accelerating REDD+ with a jurisdictional approach. LEAF uses the Architecture for REDD+ 37 Transaction, The REDD+ Environmental Excellence Standard (ART-TREES), is coordinated by 38 Emergent, a non-profit intermediary between tropical countries and the private sector. Three 39 jurisdictions in Brazil and two countries have already submitted concept notes to ART to receive results- 40 based payments. REDD+ initiatives with a jurisdictional approach have also been adopted in various 41 markets, such as the CORSIA (Maguire 2021). In addition to Brazil, Indonesia has attracted significant 42 interest as a host country for REDD+. Indonesia ranks second, after Brazil, as the largest producer of 43 deforestation-related GHG emissions (Zarin et al. 2016), but it has committed to a large reduction of 44 deforestation in its NDC (Government of Indonesia 2016). Australia has collaborated on scientific 45 research and emission reduction monitoring (Tacconi 2017). It took a while, however, before emission 46 reductions were witnessed (Meehan et al. 2019). The expansion of commodity plantations, however, 47 conflict with reduction ambitions (Anderson et al. 2016; Irawan et al. 2019) In addition to 48 implementation at the site and jurisdictional levels, legal enforcement (Tacconi et al. 2019) as well as 49 policy and regulatory reforms (Ekawati et al. 2019) appears to be needed. | 2438 - 2438 | | | |
| IPCC_AR6_WGIII_Full_Report | 4 Increases in trans-Arctic shipping and tourism activities with sea ice loss are also forecast to have strong 5 regional effects due to ships' gas and particulate emissions (Stephenson et al. 2018). | 2443 - 244 | Impact | | |
| IPCC_AR6_WGIII_Full_Report | 6 The Kyoto Protocol required Annex I parties to pursue emissions reductions from aviation and marine 7 bunker fuels by working through IMO and ICAO (UNFCCC 1997, Art. 2.2). Limited progress was 8 made by these organisations on emissions controls in the ensuing decades (Liu 2011b), but greater 9 action was prompted by conclusion of the SDGs and Paris Agreement (Martinez Romera 2016), 10 together with unilateral action, such as the EU's inclusion of aviation emissions in its Emissions Trading 11 Scheme (ETS) (Dobson 2020). | 2443 - 2443 | | | |
| IPCC_AR6_WGIII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS Final Government Distribution Chapter 14 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 14-85 Total pages: 155 1 Climate justice has been variously defined, but centres on addressing the disproportionate impacts of 2 climate change on the most vulnerable populations and calls for community sovereignty and functioning 3 (Schlosberg and Collins 2014; Tramel 2016). Contemporary climate justice groups mobilise multiple 4 strands of environmental justice movements from the Global North and South, as well as from distinct 5 indigenous rights and peasant rights movements, and are organised as a decentralised network of 6 semiautonomous, coordinated units (Claeys and Delgado Pugley 2017; Tormos-Aponte and García- 7 López 2018). The climate justice movement held global days of protest in most of the world's countries 8 in 2014 and 2015, and mobilised another large campaign in 2018 (Almeida 2019). The polycentric 9 arrangement of the global climate movement allows simultaneous influence on multiple sites of climate 10 governance, from the local to the global levels (Tormos-Aponte and García-López 2018). | 2445 - 244 | Impact | | INDG |

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| IPCC_AR6_WGII I_Full_Report | 32 The Paris Agreement's preamble explicitly recognises the importance of engaging "various actors" in 33 addressing climate change, and the decision adopting the Agreement created the Non-State Actor Zone 34 for Climate Action platform to aid in scaling up these efforts. Specific initiatives have also been taken 35 to facilitate participation of particular groups, such as the UNFCCC's Local Communities and 36 Indigenous Peoples Platform, which commenced work in Katowice in 2019. Climate movements based 37 in the Global South, as well as in Indigenous territories, are playing an increasingly important role in 38 transnational negotiations through networks such as the Indigenous Peoples Platform. These groups 39 highlight the voices and perspectives of communities and peoples particularly affected by climate 40 change. For instance, the Pacific Climate Warriors is a grassroots network of young people from various 41 countries in the Pacific Islands region whose activities focus on resisting narratives of future 42 inevitability of their Pacific homelands disappearing, and re-envisioning islanders as warriors defending 43 rights to homeland and culture (McNamara and Farbotko 2017). Youth global climate activism, 44 particularly involving young Indigenous climate activists, is another notable recent development. | 2446 - 244 | Impact | | INDG |
| IPCC_AR6_WGII I_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS Final Government Distribution Chapter 14 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 14-88 Total pages: 155 1 In the same vein, in 2010 FAO delivered the Framework for Assessing and Monitoring Forest 2 Governance. The Framework draws on several approaches currently in use or under development in 3 major forest governance-related processes and initiatives, including the World Bank's Framework for 4 Forest Governance Reform. The Framework builds on the understanding that governance is both the 5 context and the product of the interaction of a range of actors and stakeholders with diverse interests 6 (FAO 2010). For example, UNFCCC and UN-REDD program focus on REDD+ and UNEP focus on 7 TEEB (a global initiative focusing on the economics of ecosystems and biodiversity) institutional 8 mechanisms have been conceptualized as a 'win-win-win' for mitigating climate, protecting 9 biodiversity and conserving indigenous culture by institutionalizing payments on carbon sequestration 10 and biodiversity conservation values of ecosystems services from global to local communities. These 11 mechanisms include public-private partnership, and non-governmental organization participation. | 2448 - 244 | Prot-Adapt-Mitig- | | INDG |
| IPCC_AR6_WGII I_Full_Report | 12 13 15.2.3 Impact of COVID-19 pandemic 14 The macroeconomic headwinds have worsened dramatically with the onset of COVID-19. Almost two 15 years after the pandemic started, it is still too uncertain and early to conclude impacts of the pandemic 16 until 2025-2030, especially as they affect climate finance. Multiple waves of the pandemic, new virus 17 mutations, accumulating human toll, and growing vaccine coverage but vastly differing access across 18 developed versus developing regions are evident. They are causing divergent impacts across sectors 19 and countries, which combined with the divergent ability of countries and regions to mount sufficient 20 fiscal and monetary policy actions imply continued high uncertainty on the economic recovery paths 21 from the crisis. The situation remains more precarious in middle and low-income developing countries 22 (IMF 2021a). While recovery is happening, the job losses have been large, poverty rates have climbed, 23 public health systems are suffering long-term consequences, education gains have been set back, public 24 debt levels are higher (5-10% of GDP higher), financial institutions have come under longer-term stress, 25 a larger number of developing countries are facing debt distress, and many key high-contact sectors 26 such as tourism and trade will take time to recover (Eichengreen et al. 2021). The implication is 27 negative headwinds for climate finance with public attention focused on pandemic relief and recovery 28 and limited (and divergent) fiscal headroom for a low carbon transition, with considerable uncertainties 29 ahead (Hepburn et al. 2020b; Maffettone and Oldani 2020; Steffen et al. 2020). | 2530 - 253 | Impact | | |
| IPCC_AR6_WGII I_Full_Report | 32 On the one hand, each scenario is associated with a warming path, which in turn, on the basis of the 33 results from WGII, implies certain levels of physical risk (see WGII Chapter 16). However, climate 34 impacts are not accounted for in the scenarios. Moreover, levels of risk may vary with the Reason for 35 Concern (RFC, ibidem) and with the speed in the implementation of adaptation. On the other hand, 36 while mitigation can come with transition risk, in the case of lack of coordination among the actors, as 37 discussed earlier in this section, this is not modelled explicitly in the trajectories, since the financial 38 sector is not represented in underlying models. The scientific state of the art in climate-related financial 39 risk offers an analysis that is not yet comprehensive of both the physical and transition risk dimensions 40 in the same quantitative framework. However, decision makers can follow a mixed approach where 41 they can combine quantitative risk assessment for transition risk with more qualitative risk analysis 42 related to physical risk. | 2569 - 256 | ʼrot-Adapt-Mitig-Impac | | |

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| IPCC_AR6_WGII I_Full_Report | 7 Considering the need for responses to both, short-term liquidity issues and long-term fiscal space, 8 current G20/IMF/World Bank debt service suspension initiatives are focused the liquidity issue rather 9 than underlying problems of more structural nature of many low-income (Fresnillo 2020). In order to 10 ensure fiscal space for climate action in the coming decade a mix between debt relief, deferrals of 11 liabilities, extended debt levels and sustainable lending practices including new solidarity structures 12 need to be considered in addition to higher levels of bilateral and multilateral lending to reduce 13 dependency on capital markets and to bridge the availability of sustainably structured loans for highly 14 vulnerable and indebted countries. More standardised debt-for-climate swaps, a higher share of GDP 15 linked bonds or structures ensuring (partial) debt cancellation in case countries are hit by physical 16 climate change impacts/shocks appear possible. The "hurricane" clause introduced by Grenada, or 17 wider natural disaster clauses provide issuers with an option to defer payments of interest and principal 18 in the event of a qualifying natural disaster and can reduce short-term debt stress (UN AAAA Art. 102) 19 (UN 2015a). A mainstreaming of such clauses has been pushed by various international institutions. | 2581 - 258 | Impact | | |
| IPCC_AR6_WGII I_Full_Report | 17 There has also been growing interest in social drivers, motivated by the recognition of social issues, 18 such as unemployment and public health, linked to the deployment of innovative low-carbon 19 technologies (Altantsetseg et al. 2020). Policy and social factors and the diverse trajectories of 20 innovation are influenced by regional and national conditions (Tariq et al. 2017), and such local needs 21 and purposes need to be considered in crafting international policies aimed at fostering the global 22 transition towards increased sustainability (Caravella and Crespi 2020). From this standpoint, a 23 multidimensional, multi-actor systemic innovation approach would be needed to enhance global 24 innovation diffusion (de Jesus and Mendonça 2018), especially if this is to lead to overall sustainability 25 improvements rather than resulting in new sustainability challenges. | 2682 - 2682 | | | |
| IPCC_AR6_WGII I_Full_Report | 22 23 16.3.1 Frameworks for analysing technological innovation processes 24 The resulting overarching framework that is commonly used in the innovation scholarship and even 25 policy analyses is termed as "innovation system", where the key constituents of the systems are actors, 26 their interactions, and the institutional landscape, including formal rules, such as laws, and informal 27 restraints, such as culture and codes of conduct, that govern the behaviour of the actors (North 1991). | 2702 - 2702 | | | |
| IPCC_AR6_WGII I_Full_Report | 5 Systemic failures include infrastructural failures; hard (e.g., laws, regulation) and soft (e.g., culture, 6 social norms) institutional failures; interaction failures (strong and weak network failures); capability 7 failures relating to firms and other actors; lock-in; and directional, reflexivity, and coordination failures 8 (Klein Woolthuis et al. 2005; Chaminade and Esquist 2010; Weber and Rohracher 2012; Wieczorek 9 and Hekkert 2012; Negro et al. 2012). By far most of the literature that unpacks such failures and 10 explores ways to overcome them is on energy-related innovation policy. For example, Table 16.6 11 summarizes a meta-study (Negro et al. 2012) that examined cases of renewable energy technologies 12 trying to disrupt incumbents across a range of countries to understand the roles, and relative importance, 13 of the 'systemic problems' highlighted in Section 16.3.1. | 2705 - 2705 | | INTANBILE | |
| IPCC_AR6_WGII I_Full_Report | 14 END BOX 16.4 HERE 15 16 There are many definitions of policy mixes from various disciplines (Rogge et al. 2017), including 17 environmental economics (Lehmann 2012), policy studies (Kern and Howlett 2009) and innovation 18 studies. Generally speaking, a policy mix can be characterised by a combination of building blocks, 19 namely elements, processes and characteristics, which can be specified using different dimensions 20 (Rogge and Reichardt 2016). Elements include (i) the policy strategy with its objectives and principal 21 plans and (ii) the mix of policy instruments, and (iii) instrument design. The content of these elements 22 is the result of policy processes. Both elements and processes can be described by their characteristics 23 in terms of the consistency of the elements, the coherence of the processes, and the credibility and 24 comprehensiveness of the policy mix in different policy, governance, geography and temporal context 25 (Rogge and Reichardt 2016). Other aspects in the evaluation of policy mixes include framework 26 conditions, the type of policy instrument and the lower level of policy granularity, namely design 27 elements or design features (del Río 2014; del Río and Cerdá 2017). In addition, many have argued the 28 need to craft policies that affect different actors in the transition, some supporting and some 29 'destabilising' (see e.g. Kivimaa and Kern (2016) and Geels (2002)). | 2717 - 2717 | | | |

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| IPCC_AR6_WGIII_Full_Report | 12 Patent systems aim to promote innovation and economic growth, by stimulating both the creation of 13 new knowledge and diffusion of that knowledge (high evidence, high agreement). National patent 14 systems, as institutions, play a central role in theories on national innovation systems (high evidence, 15 strong agreement). Patent systems are usually instituted to promote innovation and economic growth 16 (Nelson and Mazzoleni 1996; Machlup and Penrose 1950; Encaoua et al. 2006). Some countries 17 explicitly refer to this purpose in their law or legislation – for instance, the US Constitution states the 18 purpose of the US IP rights system to "promote the progress of science and useful arts". Patent systems 19 aim to reach their goals by trying to strike a balance between the creation of new knowledge and 20 diffusion of that knowledge (Scotchmer and Green 1990; Devlin 2010; Anadon et al. 2016b). They 21 promote the creation of new knowledge (e.g. technological inventions) by providing a temporary, 22 exclusive right to the holder of the patent, thus providing incentives to develop such new knowledge 23 and helping parties to justify investments in research and development. They promote the diffusion of 24 this new knowledge via the detailed disclosure of the invention in the patent publication, and by 25 enabling a 'market for knowledge' via the trading of patents and the issuance of licenses (Arora et al. | 2735 - 2735 | | | |
| IPCC_AR6_WGIII_Full_Report | 10 11 16.4.7 Sub-national innovation policies and industrial clusters 12 Research examining the impacts of sub-national policies on innovation and competitiveness is sporadic 13 – regional variations have been quantitatively assessed in US or China, or with case studies in these and 14 other countries. Research on wind energy in the United States, distributed PV balance of systems in 15 China, and renewable energy technologies in Italy have found that policies that incentivised local 16 demand were associated with inducing innovation, measured with patents (Fu et al. 2018; Gao and Rai 17 2019; Corsatea 2016). Different policies may have different impacts – for example, in the United States 18 state-level tax incentives and subsidies induced innovation within the state; but for renewable portfolio 19 standards policies in other states were associated with innovation, because of impact on demand, but 20 own-state policies were not (Fu et al. 2018). Research has also noted that the outcomes of policy and 21 regulation on innovation are spatially heterogenous, because of differences in local planning authorities 22 and capabilities (Song et al. 2019; Corsatea 2016). | 2737 - 273 | Impact | | |
| IPCC_AR6_WGIII_Full_Report | 8 9 16.5.2 Objectives and roles of international technology transfer and cooperation efforts 10 International efforts involving technology transfer can have different objectives and roles. These 11 include access to knowledge and financial resources as well as promotion of new industries in both the 12 developed and recipient country (Huh and Kim 2018). Based on an econometric analysis of 13 international technology transfer factors and characteristics of Clean Development Mechanism (CDM) 14 projects, Gandenberger et al (2016) find that complexity and novelty of technologies explain whether 15 CDM project includes hardware technology transfer, and that factors like project size and absorptive 16 capacity of the host country do not seem to be drivers. Halleck Vega and Mandel (2018) argue that 17 'long-term economic relations', for instance being part of a customs union, affects technological 18 diffusion between countries for the case of wind energy, and indicate that this has resulted in low-19 income countries being largely overlooked. | 2740 - 2740 | | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | 7 Contributions of indigenous people (Díaz et al. 2019), heritage agriculture (Koohafkan and Altieri 8 2010) and peasants agroecological knowledge (Holt-Giménez 2002) to technological innovation offer 9 a wide array of options for management of land, soils, biodiversity and enhanced food security without 10 depending on modern, foreign agricultural technologies (Denevan 1995). In farming agriculture and 11 food systems, innovation and technology based on nature could help to reduce climate change impacts 12 (Griscom et al. 2017). Evidence suggests that there are benefits to integrating tradition with new 13 technologies in order to design new approaches to farming, and that these are greatest when they are 14 tailored to local circumstances (Nicholls and Altieri 2018). | 2759 - 275 | Impact | | INDG |

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| IPCC_AR6_WGIII_Full_Report | 15 16 Accelerating the transition to sustainability will be enabled by explicit consideration being given 17 to the principles of justice, equality and fairness. Interventions to promote sustainability 18 transitions that account for local context (including unequal access to resources, capacity and 19 technology) in the development process are necessary but not sufficient in creating a just 20 transition (low evidence, high agreement). {17.4.6} 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 17 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 17-7 Total pages: 99 1 2 17.1 Introduction 3 This chapter focuses on the opportunities and challenges for "accelerating the transition in the context 4 of sustainable development." The chapter suggests that accelerating transitions in the context of 5 sustainable development requires more than concentrating on speed. Rather, it involves expediting the 6 pace of change (speed) while also removing the underlying drivers of vulnerability and high emissions 7 (quality and depth) and aligning the interests of different communities, regions, sectors, stakeholders 8 and cultures (scale and breadth). One key to enabling deep and broad transitions is integrating the views 9 of different government agencies, businesses and non-governmental organizations (NGOs) in transition 10 processes. Another critical driver of deep and broad transitions is engaging and empowering workers, 11 youth, women, the poor, minorities and marginalized stakeholders in just, equitable and inclusive 12 processes. The result of such processes will be the transformation of large-scale socioeconomic systems 13 to restore the health and well-being of the planet and the people on it. | 2820 - 2821 | | | |
| IPCC_AR6_WGIII_Full_Report | 20 17.1, the reference to "in the context of sustainable development" suggests that sustainable transitions 21 require more than speed, also necessitating removing the underlying drivers of vulnerability and high 22 emissions (quality and depth of transitions) while also aligning the interests of different individuals, 23 communities, sectors, stakeholders and cultures (scale and breadth of transitions). | 2824 - 2824 | | | |
| IPCC_AR6_WGIII_Full_Report | 28 29 An extensive literature has examined how the international climate agreements and architecture 30 influence collaboration across countries regarding climate and sustainable development to support a 31 transition (Bradley 2005). For example, international institutions offer opportunities for governments 32 and other actors to share new perspectives on integrated solutions (Cole 2015). For some observers, 33 however, decades of difficulties in crafting a comprehensive climate-change agreement and the 34 resulting fragmented climate-policy landscape have been inimical to the collaboration needed for a 35 transition (Chapter 1 and 13; Nasiritousi and Bäckstrand 2019; van Asselt 2014). Yet others see the 36 potential for more incremental cooperation across countries, even without a single, integrated forms of 37 climate governance (Keohane and Victor 2016). | 2826 - 2826 | | | |
| IPCC_AR6_WGIII_Full_Report | 54 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 17 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 17-15 Total pages: 99 1 Many of the above-mentioned beliefs and values that support climate actions have spread through 2 expanding interests in conservationist world views, indigenous cultures (see e.g., Lockhart 2011) and 3 branches of neuroscience and psychology that suggest different notions of the self (Hüther 2018; Lewis 4 2016; Seligman and Csikszentmihalyi 2014). These beliefs and values can also be spread through 5 meditation, yoga or other social practices that encourage lower carbon lifestyles (Woiwode and 6 Woiwode 2019). Another channel for spreading climate concerns is sustainability culture, which is 7 premised on connecting people and communities, and has also benefited from the internet and digital 8 technologies that support these connections (see e.g., Bradbury 2015; Scharmer 2018). The spread of 9 this culture, in turn, has led to the creation of social fields that allow changes to happen ( (see e.g., 10 Gillard et al. 2016) or has promoted low-carbon thinking and related behavioural changes (O'Brien 11 2018; Veciana and Ottmar 2018). Studies of social contagions may also offer insights into the 12 mechanisms that lead to the adoption of new values and related climate actions (see e.g., Iacopini et al. | 2828 - 282 | Prot-Adapt-Mitig- | INTANBILE | INDG |
| IPCC_AR6_WGIII_Full_Report | 23 24 17.2.5 Conclusions 25 This section has surveyed several explanations for interventions that can give rise to transitions. The 26 review suggests that there are several differences between these various perspectives. Whether 27 individuals, organisations, markets or sociotechnical systems drive or undermine transitions is a key 28 distinction. These differences have implications for the evidence these claims draw on in support of 29 their arguments. For instance, some of the explanations tend to employ qualitative evidence to explain 30 changes in attitudes at the individual or community levels as paving the way for broader changes to 31 cultures and belief systems. Others assess how institutional arrangements can be reformed in order to 32 align climate with the sustainable development agenda to enable a transition. | 2830 - 2830 | | | |

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| IPCC_AR6_WGIII_Full_Report | 4 5 Okereke et al. (2019) offer important generic conclusions on green industrialisation and the transition 6 based on a study of socio-technical transition in Ethiopia. The importance of drivers for changes in 7 terms of clear policy goals and government support for green growth and climate policies, as well as 8 support from a strong culture of innovation, is emphasized. The study also identifies key barriers in 9 relation to stakeholder interactions, the availability of resources and the ongoing tensions between 10 ambitions for high economic growth and climate change. Green innovation in industry critically 11 depends on regulations. Gramkow and Anger-Kraavi (2018) have assessed the role of fiscal policies in 12 greening Brazilian industry based on an econometric analysis of 24 manufacturing sectors. They 13 conclude that instruments like low-cost finance for innovation and support to sustainable practices 14 effectively promote green innovation. | 2855 - 285 | Impact | | |
| IPCC_AR6_WGIII_Full_Report | 43 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 17 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 17-51 Total pages: 99 1 2 3 Figure 17.1 Trade-offs and synergies between sectoral mitigation options and the SDGs 4 5 6 Most of the energy sector options are assessed as having synergies with several SDGs, but there could 7 be mixed synergies and trade-offs between SDG 2 'zero hunger' for wind and solar energy, and for 8 hydropower due to land-use conflicts and fishery damage. Offshore wind could also have both synergies 9 and trade-offs with SDG 14 'life below water' dependent on scale and implementation site, and it is 10 emphasized that land-use should be coordinated with biodiversity concerns. Both wind and solar energy ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 17 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 17-52 Total pages: 99 1 are assessed as having trade-offs with SDG 12 'responsible production and consumption' due to 2 significant material consumption and disposal needs. | 2864 - 286 | 'rot-Adapt-Mitig-Impa( | | |
| IPCC_AR6_WGIII_Full_Report | 49 50 Indeed, individual actions are necessary but insufficient to deliver transformative mitigation, and it is 51 suggested that this be coupled with collective actions to accelerate the transition to sustainable 52 development (Dugast et al. 2019). Actors with conflicting interests will compete to frame mitigation 53 technologies that either "build or erode" the legitimacy of the technology, contested framing sites that 54 can occur between incumbent and emerging actors or between actors in new but competing spaces ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 17 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 17-56 Total pages: 99 1 (Rosenbloom et al. 2016). How narratives are built around desired development pathways and specific 2 emerging technologies, as well as how local values are integrated into visions of the future, have 3 relevance for how these experiments are managed and enabled to expand (Horcea-Milcu et al. 2020; 4 Lam et al. 2020). | 2869 - 287 | Prot-Adapt-Mitig- | | |
| IPCC_AR6_WGIII_Full_Report | 18 19 It was Theory-U (Scharmer 2018, building on the work of scholars like Schein, Lewin or Senge) that 20 inspired a so-called "massive open online course" (MOOC) jointly initiated by the Bhutan Happiness 21 Institute and German Technical Assistance (GIZ) in 2015, since when it has been developed further and 22 adapted to transform business, society and self as one example of how social movements can go together 23 with science and education. It brings together people from different professions, cultures and continents 24 in shared discussions and practices of sustainability. It also included marginalised communities and is 25 shifting towards more sustainable lifestyles in all sectors (Nikas et al. 2020), including climate action. | 2870 - 287 | Prot-Adapt-Mitig- | INTANBILE | |
| IPCC_AR6_WGIII_Full_Report | 26 27 Moreover, approaches like the "Art of Hosting" (Sandfort and Quick 2015) and qualitative research 28 methods like storytelling and first-person research, as well as second-person inquiries, for example 29 (Scharmer, C, Kaufer 2015; Trullen and Torbert 2004; Varela 1999), have been employed to bridge 30 differences in cultures and sciences, as well as to forge connections between those working on climate 31 change and sustainable development. Likewise, experiential tools, simulations and role-playing games 32 have been shown to increase knowledge of the causes and consequences of climate change, the sense 33 of urgency around action and the desire to pursue further learning (Ahamer 2013; Eisenack and Reckien 34 2013; Hallinger et al. 2020; Rooney-Varga et al. 2020). | 2870 - 2870 | | | |

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| --- | --- | --- | --- | --- | --- |
| IPCC_AR6_WGII_Full_Report | 49 50 A related line of inquiry involves education for sustainable development (ESD). This builds on the 51 UNESCO programme, 'ESD for 2030', and involves core values like peace culture, valuing cultural 52 diversity and living global citizenship. One of the core insights from research on ESC is lifelong 53 education continuing outside the classroom, a lifelong learning process that involves sustained actions 54 by all ages and social segments (see e.g., Hume and Barry 2015) and achieving collaboration (Munger 55 and Riemer 2012). Some authors have pointed to good levels of communication either directly or ACCEPTED VERSION SUBJECT TO FINAL EDITS Final Government Distribution Chapter 17 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 17-57 Total pages: 99 1 through the internet as the key to facilitating this learning (Sandfort and Quick 2015). Others have noted 2 that transformative learning – that is, deepening the learning process – is critical because it helps to 3 induce both shared awareness and collective actions (see e.g., Brundiers et al. 2010; Singleton 2015; 4 Wamsler and Brink 2018). | 2870 - 2871 | | INTANBILE | |
| IPCC_AR6_WGII_Full_Report | 33 However, government agencies with climate and other remits do not always work well together: the 34 absence of coordination and consensus building mechanisms can further deepen inter-agency conflicts 35 that stall a transition. These challenges appear not only within but also between levels of decision- 36 making. Studies of developing megacities, for instance, have found the lack of mechanisms promoting 37 vertical cross-level integration to be a sizable constraint on decarbonisation (Canitez 2019). Differences 38 in perspectives across non-state actors can similarly frustrate transitions in areas such as green buildings 39 (Song et al. 2020). | 2873 - 2873 | | | |
| IPCC_AR6_WGII_Full_Report | 14 Furthermore, this is how existing institutions interact with ideas that often strengthen lock-ins. To 15 illustrate, studies have shown that the status-quo orientations of leaders (including decision-makers' 16 disciplinary backgrounds, world views and perceptions of risk) (Willis 2018), as well as the 17 organizational culture and management paradigms within which they operate, affect the speed and 18 ambitions of climate policies (Rickards et al., 2014). | 2874 - 287 | Impact | | |
| IPCC_AR6_WGII_Full_Report | 42 43 Intersectional theory can shine a light on the hidden costs of resource extraction, as well as renewable 44 energy development (see, for instance, (Chatalova and Balmann 2017), which go beyond environmental 45 or health risks to include the socio-cultural impacts on both communities adjacent to these sites and 46 those who work in them (Daum 2018). Indeed, development decisions often do not properly integrate 47 the burdens and risks placed on marginalized groups, like indigenous peoples, while risk assessments 48 tend to reinforce existing power imbalances by failing to differentiate between how benefits and risks 49 might impact on certain groups (Healy et al. 2019; Kojola 2019). In some cases, such as the deployment 50 of small-scale solar power in Tanzania by a non-profit organization, an explicit gender lens on the 51 impacts of energy poverty revealed the significant socio-economic benefits of improving access to 52 renewable energy (Gray et al. 2019). | 2875 - 287 | Impact | | INDG |
| IPCC_AR6_WGII_Full_Report | 20 21 22 17.5 Conclusions 23 This chapter has been concerned to assess the opportunities and challenges for acceleration in the 24 context of sustainable development. As such, many of the claims reviewed involve not only increasing 25 the speed of the transition but also ensuring that it is just, equitable and delivers a wider range of 26 environmental and social benefits. A sustainability transition requires removing the underlying drivers 27 of vulnerability and high emissions (quality and depth) while aligning the interests of different 28 communities, regions, sectors, stakeholders and cultures (scale and breadth). | 2877 - 2877 | | INTANBILE | |

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|---|---|---|---|---|---|
| Adapting to Change (2011) | The dynamic history of forests Forests often seem eternal, stable representations of mature and stately ecosystems. But the venerable concept of relatively stable 'climax' forest ecosystems that are hundreds, or even thousands, of years old has now been replaced by the recognition that forests are in a constant state of change, requiring more adaptive forms of management (Hollings, 1978). Resource managers now need to consider the dynamic forces of fires, storms, droughts, climate change, and other natural factors with the usual human impacts such as logging, introduction of non-native species, building of roads, planting of vast plantations of genetically identical trees, and so forth. | 11 - 11 | Prot-Adapt-Mitig-Impact | | |
| Adapting to Change (2011) | Isolating a forest by excessive land use changes around it will have significant repercussions on its ability to maintain its composite biodiversity and to provide ecosystem services, rendering it more susceptible to disturbance. In this regard, no forest is an island. Ironically, in strictly legal terms, World Heritage forests tend to be managed as if there were islands. They must be designated with bound�aries that indicate which government agency has responsi�bility for maintaining its World Heritage values. As a result, though a forest is extensively connected to the lands around it, management is often designed as though they were closed systems and it is often forced to function with little interaction or mandate to engage with landscape level stakeholders who may have an influence on systems, which in turn may affect World Heritage forests. The long�term well being of World Heritage forests is therefore at risk from both ecological and institutional isolation. | 12 - 12 | Prot-Adapt-Mitig-Impact | | |
| Adapting to Change (2011) | The evolutionary forces of isolation may be disrupted, fires may find it easier to spread, and disease may no longer be impeded by buffer zones. These risks will need to be incor�porated, as connectivity becomes a more central concern in forest management (Ewers and Kapos, this volume). | 12 - 12 | Prot-Adapt-Mitig-Impact | | |
| Adapting to Change (2011) | 14 11 Adapting to Change – The State of Conservation of World Heritage Forests in 2011<br>Reducing external impacts on World Heritage forests Global demand for forest products continues to expand, though the rate of increase is surprisingly modest, increasing by only 0.4 per cent per year since 1980. But over the same time, paper consumption increased at an annual rate of 3.2 per cent, and sawn timber and wood panels increased by 0.8 per cent per year (Ajani, 2011). | 13 - 14 | Prot-Adapt-Mitig-Impact | | |
| Adapting to Change (2011) | Adapting to climate change Once monitoring has provided information on changes taking place, the next and more complex challenge lies in implementing effective adaptation measures. All ecosys�tems change through time. The challenge facing us today is to understand where changes will threaten the Outstanding Universal Values that qualify a site as World Heritage, and understand if and how we can do some�thing about it, and when we cannot, then act on that information. Adaptive strategies include land management (i.e. establishing ecological corridors to allow the migra�tion of plants and animals, and buffers to increase the resilience of sites), on-site management (i.e. encouraging or discouraging vegetative patterns), and management of human impacts (i.e. fire risk). It is likely that a systematic and full response to climate change for all World Heritage forest sites will be restricted by financial capacity. To prior�itize action, the sites that are at highest risk, the drivers of that risk, and those with potential for greatest adaptive opportunities, all need to be identified. | 22 - 22 | Prot-Adapt-Mitig-Impact | | |
| Adapting to Change (2011) | Therefore, there will always be uncertainty about a predicted future. That uncertainty requires adaptive management (i.e. taking action on the ground, measuring effects, and changing management as necessary). It also requires being routinely aware of the growth in model effectiveness, so that management is based on reasonable climate scenarios. | 23 - 23 | Prot-Adapt-Mitig-Impact | | |
| Adapting to Change (2011) | The most significant decision to be made regarding climate change adaptation and ecological monitoring is the audience for the results, and the actions one wishes that audience to take. A proactive climate-change response plan for a World Heritage forest should include stakeholder definition (i.e. who are the people who care about and have the ability to act upon impacts of climate change at the site?). A monitoring programme, including both climatic and ecological variables will inform those stakeholders and guide their actions. An actively engaged site manager will be able to provide data and information about his/her site, and the ways climate-related changes are affecting that site, or might affect it in the future. A stakeholder group will be able to develop and assess large scale adaptive strategies such as the purchase or manage�ment of adjacent lands, the formulation of land use poli�cies designed to encourage certain behaviours among land owners, or management of human impacts (i.e. better fire control capacity). | 25 - 25 | Prot-Adapt-Mitig-Impact | | |

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| Adapting to Change (2011) | A serious constraint faced by all World Heritage forest site managers is resource limitation. Each site has a rela�tively limited budget that can be invested in manage�ment, M&A, and all the other demands placed on the site's budget. Investing in climatic and/or ecological monitoring represents one more demand on limited resources; setting priorities among those competing demands is a central function of management. There are at least two resources that would help an individual site manager evaluate climate change related risks compared to competing priorities: • Global models that evaluate relative climate change risk at World Heritage sites (i.e. Perry, 2011, Epple et al., 2010) identify sites perceived to be most at risk, and identify perceived causal factors (i.e. what makes one site more at risk than another). Sites generally perceived to be at higher risk will find monitoring an important investment. Variables perceived to drive vulnerability at a given site will often be useful components of a moni�toring programme. | 25 - 25 | Prot-Adapt-Mitig-Impact | | |
| Adapting to Change (2011) | Summary Some World Heritage forest sites are at much higher risk of climate related changes than others. Recent attempts to assess relative climate change risk among World Heritage sites assist individual site managers in under�standing the magnitude of the risks they face, as well as the specific on-site variables most strongly driving such risk and therefore, most likely to change. Carefully designed and implemented ecological and climatic moni�toring programmes that actively engage a strong stake�holder base will be most effective in detecting and responding to climate induced changes. A proactive strategy will ensure the best decisions. Elements of such a strategy should include: 1) developing a World Heritage forest adaptation toolkit, 2) engaging the World Heritage forest community (i.e. managers and staff of the 104 designated forest sites) in an active discussion of antici�pated, climate induced changes, and 3) pairing sites to share analytical ideas and approaches. Actions such as those will increase the probability that climate change impacts are detected early and that proactive, adaptive strategies are identified and considered in a timely way. | 25 - 25 | Prot-Adapt-Mitig-Impact | | |
| Adapting to Change (2011) | 3. Conservation Science Group, Department of Zoology, University of Cambridge, Downing Street, Cambridge CB2 3EJ, UK.<br>WH WH WH One set of these relates to corridors of forest, such as riparian forests that are often preserved along river margins, and may connect a World Heritage forest to other forest areas. Corridors are known to promote the dispersal of species between habitat patches, thereby reducing biodiversity loss within them (Damschen et al., 2006). The likely efficacy of a corridor can be assessed using four criteria: (a) wide corridors are preferable to narrow corridors, as many species avoid forest edges and are therefore unlikely to move through a narrow strip of forest (Ewers and Didham, 2007); (b) shorter corridors are more likely to allow successful dispersal between patches than long corridors; (c) similarly, a corridor should ideally be continuously forested with no breaks, such as might be created by roads crossing the corridor (this is not to say that a 'broken' corridor will not function; as long as a species will cross small gaps then the individual patches of forest along that corridor can act as 'stepping stones', facilitating the movement of a species from one location to another); (d) finally, the size of the forest patch at the other end of the corridor is a strong determinant of the size of populations inhabiting that patch and therefore the likelihood of individuals leaving the patch to disperse along the corridor (Hanski, 1998). Corridors that connect a World Heritage forest to a large forest patch are likely to have a larger beneficial effect for the World Heritage forest than those connecting to a small forest patch. | 27 - 28 | Prot-Adapt-Mitig-Impact | | |
| Adapting to Change (2011) | http://cmsdata.iucn.org/downloads/forests_1.pdf Adapting to changes 31 2<br>Introduction A shift from the traditional exclusionary conservation paradigm towards a more integrative landscape approach can be seen in the management philosophies of protected areas (PAs) (Phillips, 2003). This derives partly from a better scientific understanding of how humans have been shaping ecosystems and landscapes, increasing recognition of local and indigenous communities as well as uncertainties regarding the potential impacts of global climate change (Sayer and Maginnis, 2005). In addition, the frequent shortcomings in funding for PA manage�ment is an incentive for exploring new possibilities to monetize ecosystem services that are delivered by PAs (de la Harpe et al., 2004). In this regard, payment schemes for carbon sequestration services in the context of Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (REDD+), as currently negotiated under the United Nations Framework Convention on Climate Change (UNFCCC), might play a considerable role as an additional source of long-term funding for forest PAs in the future (Dudley, 2008; Harris et al., 2008). | 29 - 30 | Prot-Adapt-Mitig-Impact | | INDG |
| Adapting to Change (2011) | Benefits and risks of REDD+ for biodiversity Additional benefits for biodiversity that can be derived from REDD+ include the conservation of forest biodiversity beyond the mere protection of forest cover, the establish�ment of corridors between PAs (see Chapter 4 on connec�tivity) (Wendland et al., 2009), the reduction of forest fire incidents (Stickler et al., 2009) and securing the sustain�able delivery of forest ecosystem services (UN-REDD, 2009). Furthermore, there are opportunities for enhancing biodiversity monitoring in and outside PAs. | 30 - 30 | Prot-Adapt-Mitig-Impact | | |

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| Adapting to Change (2011) | Furthermore, there is the risk of inter-ecosystem leakage since forest conservation under REDD+ can trigger a shift of land use conversion pressures to non-forest ecosystems with high biodiversity, such as peatlands or grasslands (Klink and Machado, 2005; Miles and Kapos, 2008; Paoli et al., 2010). PAs may also be threatened by leakage if REDD+ activities outside the PAs lead to an increase in deforestation pressure within the PAs. | 30 - 30 | Prot-Adapt-Mitig-Impact | | |
| Adapting to Change (2011) | Notwithstanding these potential risks, REDD+ activities – if properly designed – can contribute to the long-term funding of PAs and to the conservation of biodiversity and ecosystem services in PAs within a landscape scale approach. World Heritage forest sites have Outstanding Universal Value (OUV) in terms of forest biodiversity and delivery of important ecosystem services (Ripley, 2007) and are therefore sites with high potential for achieving syner�gies between climate and biodiversity objectives under REDD+. The synergies between REDD+ and the long-term conservation of World Heritage forest sites are starting to be widely recognized, as demonstrated by the increasing 32 2 Adapting to Change – The State of Conservation of World Heritage Forests in 2011 REDD+ as a Contribution to Conservation and Connectivity of World Heritage Forest Sites by Steffen Entenmann and Christine B. Schmitt Institute for Landscape Management, University of Freiburg, Germany 1 1. University of Freiburg, Tennenbacher Strasse 4, D-79106 Freiburg. | 30 - 30 | Prot-Adapt-Mitig-Impact | | |
| Adapting to Change (2011) | An important conceptual framework applied by many certification schemes for assessing forest biodiversity is the High Conservation Value (HCV) concept developed by the Forest Stewardship Council (FSC). This concept recognizes six types of HCV forests and provides guidelines for moni�toring the ecological conditions and changes in forests. It also recognizes whether the project area provides habitats to species listed on the IUCN Red List of Threatened Species, as well as important ecosystem services such as the provision and storage of water and the protection of soil against erosion. | 31 - 31 | Prot-Adapt-Mitig-Impact | | |
| Adapting to Change (2011) | REDD+ activities can be an important contribution to reduce GHG emissions and improve conservation effec�tiveness in PAs of all IUCN management categories9. In PAs under IUCN categories I-IV, REDD+ measures can help in reducing illegal logging and increasing the conservation effectiveness, while in PAs under IUCN categories V-VI, REDD+ can help in reducing GHG emissions from legal forest management activities i.e. through sustainable forest management and the enhancement of carbon stocks; however, the biodiversity impacts of these activi�ties need to be carefully considered. | 34 - 34 | Prot-Adapt-Mitig-Impact | | |
| Adapting to Change (2011) | 36 2 Adapting to Change – The State of Conservation of World Heritage Forests in 2011 9. For an explanation: http://www.unep-wcmc.org/protected_areas/categories/index.html<br>It is fair to assume that conservation or the creation of forest corridors, including secondary forests or structurally rich plantations adjacent to World Heritage forest sites, usually has positive impacts on ecological connectivity. | 34 - 35 | Prot-Adapt-Mitig-Impact | | |
| Adapting to Change (2011) | Proximity to World Heritage forest sites could be taken into account when evaluating the effects on biodiversity of a REDD+ project as World Heritage forest sites per se have OUV and contain unique species and habitats. At least for the voluntary carbon market, where some buyers of carbon certificates are willing to pay a premium for carbon credits generated in projects with certified positive impacts of biodiversity, this might add value to the conservation effort and increase the price of the carbon credits. In order to keep track of the impacts on biodiversity of REDD+ in the World Heritage forest sites, objectives for biodiversity monitoring must be defined, and monitoring systems need to be established. This is automatically given if the REDD+ project takes place within the World Heritage forest site, but could also be required if it is located outside the World Heritage site, for example, the CCBA standard requires the assessment of off-site biodiversity impacts. | 35 - 35 | Prot-Adapt-Mitig-Impact | | |
| Adapting to Change (2011) | Despite a reported overall decrease in threats to World Heritage forests in recent years, the 2001–2006 Threat Intensity Coefficients for a number of tropical sites demon�strate the potential for improved management and enforcement to reduce pressures from agricultural encroachment and deforestation (Patry and Ripley, 2007; Patry, 2007b). For World Heritage forests facing consider�able encroachment, engagement with REDD+ may depend on their ability to document these threats and the resulting/potential carbon losses. | 37 - 37 | Prot-Adapt-Mitig-Impact | | |
| Adapting to Change (2011) | • The World Heritage Committee might engage with the CBD effort to maximize the biodiversity conservation outcomes of REDD+ interventions. It might contribute to the development of indicators for measuring the biodi�versity impacts of REDD+ actions. The CBD is also lobbying for a REDD+ mechanism that also prioritizes co-benefits, and the Committee might consider whether to take a similar advocacy position. | 42 - 42 | Prot-Adapt-Mitig-Impact | | |

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| Adapting to Change (2011) | Next, we examined the certification assessment reports for each of these nine operations. Among other things, the assessment report identifies areas of non-conformance – areas where the candidate forestry operation is not in compliance with FSC standards. When this happens, oper�ations are issued a Corrective Action Request, or 'CAR', that clearly specifies the action that must be taken to come into compliance with the standard. If the non�conformance is minor, the FSC certificate is awarded and the operation is given time – typically one year – to imple�ment the CAR. If the infraction is severe, a major CAR is issued and the FSC certificate is not awarded until CAR implementation is verified.6 Though not a perfect proxy for impact, we believe that the CARs issued to an operation do provide valuable insights into the areas where certification has resulted in forest management improvements. Because we were specifically interested in the changes that RA/FSC-certified companies made that might affect the adjacent World Heritage sites, we looked for CARs that required operations to take corrective actions that would: • Improve High Conservation Value Forest (HCVF) assess�ment • Conserve HCVFs • Protect rare, threatened or endangered species or their habitats • Limit the movement of invasive species • Prevent or contain forest fires • Improve worker wages or working conditions • Enhance the viability of local communities In the sections that follow, we identify those World Heritage sites with adjacent RA/FSC-certified forestry oper�ations, outline the current threats that these sites face, and describe the ways that their certified neighbours might be contributing to their effectiveness and integrity. | 45 - 45 | Prot-Adapt-Mitig-Impact | | |
| Adapting to Change (2011) | Tembec's CARs required the assessment and management of HCVF areas, and the creation of larger 'protected reserve' areas. Practices within riparian zones were also addressed, with one CAR requiring the creation of a 7- metre machine-free zone along all water bodies, except where required for stream crossings. Tembec was also required to mitigate the damages associated with mineral exploration roads in areas designated as HCVFs. | 46 - 46 | Prot-Adapt-Mitig-Impact | | |
| Adapting to Change (2011) | At the heart of the Strategic Plan are twenty ambitious but realistic targets collectively known as the Aichi Biodiversity Targets. These targets must be met over the next decade if the plan is to be realized. The implementation of the Plan coincides with the International Decade of Biodiversity 2011–2020 announced by the UN General Assembly in December 2010. There are four targets that are directly relevant to forests and protected areas, including World Heritage sites. These 2020 targets include: • to at least halve, and where feasible bring close to zero, the rate of loss of all natural habitats, including forests, and to significantly reduce degradation and fragmenta�tion (Target 5); • to manage areas under agriculture, aquaculture and sustainably managed forests (Target 7); • to conserve at least 17 per cent of terrestrial and inland water and 10 per cent of coastal and marine areas (Target 11); and 60 3 Adapting to Change – The State of Conservation of World Heritage Forests in 2011 Forests and Protected Areas: Outcomes of the Tenth Meeting of the Conference of the Parties to the Convention on Biological Diversity by Johannes Stahl, Tim Christophersen and Jason Spensley Secretariat of the Convention on Biological Diversity, Montreal, Canada<br>• to enhance the resilience and the contribution of biodi�versity to carbon stocks through conservation and restoration, including restoration of at least 15 per cent of degraded ecosystems, thereby contributing to climate change mitigation and adaptation, and to combating desertification (Target 15). | 57 - 58 | Prot-Adapt-Mitig-Impact | | |
| Adapting to Change (2011) | • Finally, decision X/33 on biodiversity and climate change contains several paragraphs related to reducing emis�sions from deforestation and forest degradation in developing countries (REDD-plus). The decision invites 62 3 Adapting to Change – The State of Conservation of World Heritage Forests in 2011 Not for food: Control of bushmeat harvesting is a key part of the CBD forest agenda. © CBD Secretariat 1. The full text of the Strategic Plan, including all the Aichi Biodiversity Targets, is available at: http://www.cbd.int/sp 2. The full texts of these decisions are available at: http://www.cbd.int/deci�sions<br>Parties and other governments to enhance the benefits for and avoid negative impacts on biodiversity from REDD-plus, and other sustainable land management and biodiversity conservation and sustainable use activities. It requests the Executive Secretary to provide advice on relevant REDD-plus safeguards for biodiversity, based on effective consultation with Parties and their views, and with the participation of indigenous and local communi�ties. It also requests the Executive Secretary to identify possible indicators that assess the contribution of REDD�plus towards achieving the objectives of the CBD, and to assess potential mechanisms that monitor the impacts of REDD-plus on biodiversity. | 59 - 60 | Prot-Adapt-Mitig-Impact | | INDG |

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| Adapting to Change (2011) | CBD LifeWeb Initiative The CBD LifeWeb Initiative facilitates financing for protected areas to conserve biodiversity, address climate change and secure livelihoods. Managed by the CBD Secretariat, LifeWeb was invited by the Conference of the Parties to the CBD in its decision IX/18(11–12), and was reinforced by decision X/31 in 2010. It provides value�added by: (i) serving as an electronic clearing house of funding priorities; (ii) supporting Parties to hold financing roundtable meetings to strengthen international coopera�tion based on national priorities for protected area systems; and (iii) recognizing financing for priorities conveyed through CBD LifeWeb. Since 2009, sixteen donor partners have provided over US$120 million in funding support for projects profiled through this clearing house. Much of this support has been for the conserva�tion and restoration of forest areas. Over thirty-five coun�tries are currently profiling further priorities, and partner�ships are being sought with support of CBD LifeWeb for an additional US$720 million. World Heritage Sites are of special relevance to CBD LifeWeb, particularly given their unique visibility and the need for good examples of ecosystem goods and services that can be derived from the effective management of protected areas.3 REDD-plus consultations In collaboration with partners, the Secretariat organizes a series of regional consultation and capacity-building workshops on REDD-plus, including on relevant biodiver�sity safeguards. The workshops aim to consult effectively with Parties on biodiversity aspects of REDD-plus. They develop advice on REDD-plus and relevant safeguards, on possible indicators to assess the contribution of REDD-plus to achieving the objectives of the CBD, and on potential mechanisms to monitor the impacts of REDD-plus on biodiversity. The workshops also contribute to capacity�building on REDD-plus. The results are intended to support both the CBD and the United Nations Framework Convention on Climate Change discussions on safeguards, as well as on the monitoring of biodiversity in the context of the forest related targets of the Strategic Plan. | 61 - 61 | Prot-Adapt-Mitig-Impact | | |
| Adapting to Change (2011) | 66 3 Adapting to Change – The State of Conservation of World Heritage Forests in 2011 Category of forest user Cash income Non-cash income Total Forest income as a percentage of total income Wealthy and average men 42 58 100 Of which forest 7 31 38 Wealthy and average women 36 64 100 Of which forest 10 34 44 Poor and very poor men 38 62 100 Of which forest 9 36 45 Poor and very poor women 32 68 100 Of which forest 12 38 50 Average contribution of cash and non�cash income to total income 37 63 100 Average contribution of forest income to total income 9 35 44 Table 1. Forest use in the village of Tenkodogo, Burkina Faso (per cent)<br>The importance of World Heritage forests World Heritage forests could play a tremendous role in promoting the essential values of forests. With 104 protected forests now recognized as World Heritage prop�erties, the network of World Heritage forests brings together the world's most outstanding forests, many of which provide the greatest value in terms of beauty, but also biodiversity, carbon storage, erosion prevention, and of course social and cultural values, which after all lie at the core of the concept of the World Heritage Convention. | 63 - 64 | Prot-Adapt-Mitig-Impact | INTANBILE | |
| Adapting to Change (2011) | The vision of human populations acting as key players in biodiversity conservation and sustainable use has been embedded in UNESCO's Man and the Biosphere (MAB) Programme since its launch in 1971. The issue of forests, infused with the notion of their ecological, economic and cultural values, has been addressed by the MAB Programme since its earliest days. From scientific projects, addressing the issues of ecological effects of increasing human activities on tropical and sub-tropical forest eco�systems, and ecological effects of different land uses and management practices on temperate and Mediterranean forest landscapes, the MAB Programme has gradually shifted its focus towards exploring how the improved protection and management of forested landscapes in and around specific sites, or biosphere reserves, could contribute to biodiversity conservation while improving social, economic and cultural well-being of resident human communities. | 65 - 65 | Prot-Adapt-Mitig-Impact | INTANBILE | |
| Adapting to Change (2011) | It is interesting to note that forty out of one hundred and three World Heritage forests 2, thus more than one-third, constitute the legally protected core area of forest biosphere reserves, with eleven located in post-Seville sites (Table 1). In this context, and bearing in mind the alarming rate of forest destruction and degradation worldwide, there is a need to explore and document ways and means in which the dual World Heritage–Biosphere Reserve designation can increase the effectiveness of long-term conservation of World Heritage forests as well as fulfilling the overall conservation and development functions of biosphere reserves. | 65 - 65 | Prot-Adapt-Mitig-Impact | | |
| Adapting to Change (2011) | • Bia Biosphere Reserve, Ghana Ghana submitted a funding request to the UNESCO Participation Programme during the 2010–2011 funding period to carry out a climate change impact assessment study on the Bia Biosphere Reserve. The aim of this study is to obtain scientific knowledge on the cause and effect relationship of climate change on the biosphere 70 3 Adapting to Change – The State of Conservation of World Heritage Forests in 2011 reserve in order to develop sound mitigation and adap�tation measures for the ecosystem. Subsequently, these mitigation and adaptation options will be integrated into the biosphere reserve's current management plans. | 67 - 68 | Prot-Adapt-Mitig-Impact | | |

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| Adapting to Change (2011) | 82 4 Adapting to Change – The State of Conservation of World Heritage Forests in 2011 Figure 2. A map of cumulative forest fires in the region between 2005 and 2009<br>Case Studies – On Connectivity 83 4 Figure 3. Climate change and biodiversity hotspots in Mesoamerica Source: Anderson, E.R., Cherrington, E.A., Flores, A.I., Perez, J.B., Carrillo R., and E. Sempris. (2008) Potential impacts of climate change on biodiversity in Central America, Mexico and the Dominican Republic. CATHALAC/USAID. Panama City, Panama, p.105.<br>Payment for Ecosystem Services The Payment for Environmental (ecosystem) Services (PES) is a promising tool for forest conservation. Two decades ago Costa Rica developed an innovative approach by establishing a fuel tax of 3.5 per cent that goes into paying forest owners a fee for the conservation of standing forests, regeneration areas and forest planta�tions. Four environmental services were recognized in the Biodiversity Law of 1996: biodiversity, water, carbon and landscape. This has allowed the country to actually double its forest cover over the last two decades, having now over 50 per cent of the country under forest, significantly contributing to re-establishing or maintaining ecological connectivity between protected area nodes. | 78 - 80 | Prot-Adapt-Mitig-Impact | | |
| Adapting to Change (2011) | Limitations of established partnerships In practice, all these partnerships have limitations to the mobilization of resources capable of supporting the efforts necessary to apply the principles of sustainable develop�ment at a larger scale that encompasses the entire DFR landscape. The low participation and awareness of local communities in terms of the World Heritage forest concept, and the absence of information on the Dja Forum, which was implemented with the help of IUCN�Central Africa (BRAC) in the 1990s, have contributed to these shortcomings. The impact of these processes on community dialogue established by the 'Model Forest Partnership' is thus still limited. In particular, the issues of biodiversity conservation have yet to be fully appreciated by local and indigenous populations. Nevertheless, they are well aware of the current threat to a number of animal and plant species, for example, the overexploitation of Moabi tree (Baillonnella Toxisperma) for economic reasons. | 84 - 84 | Prot-Adapt-Mitig-Impact | | INDG |
| Adapting to Change (2011) | Another challenge is the absence of an environmental education curriculum. The impact of the 'Model Forest Partnership' is also limited by the fact that stakeholders do not have the necessary jurisdiction or mandate that would allow them to apply their ideas directly in the field, and which would allow them the opportunity to engage in biodiversity conservation. The notable lack of dialogue among certain local stakeholders is a direct consequence of insufficient consultation and inadequate institutional�ization of a co-management system. Every one of the stakeholders has their own management plan for bio�diversity in the same area. This is the case of Geovic, a mining company exploiting cobalt and nickel ores close to the reserve. | 84 - 84 | Prot-Adapt-Mitig-Impact | | INDG |
| Adapting to Change (2011) | Citing the term employed by Klein in 1991 (cited by Bourque, 2008), a Model Forest partnership built around these stakeholders is a form of new social contract estab�lished at the local level. However, there is an urgent need to implement and reinforce the institutional bodies outlined in the Decree No. 1052/MINFOF 17 December 2007 that approved and executed the development plan for the DFR so as to ensure a stronger participation of the local population, particularly the Bakas whose survival depends directly on the forest. The Bakas fully understand the biology of animals, their reproductive cycle, their feeding habits and their migratory movements across the landscape, and are thus one of the key partners for the sustainable management of the entire DFR. The FOMOD incorporates their thoughts and positions on such current issues as forestry governance, the REDD, and anthro�pogenic climate change. As regards local economic issues, FOMOD's partners participate in discussions on the mitiga�tion of negative impacts as a result of forest exploitation and the mining of cobalt, nickel and iron. Furthermore, stimulating the local economy remains one of FOMOD's priorities so as to find a solution to the endemic poverty visible around the protected areas (Dja Faunal Reserve and Nki National Park). | 85 - 85 | Prot-Adapt-Mitig-Impact | | INDG |
| Adapting to Change (2011) | 90 4 Adapting to Change – The State of Conservation of World Heritage Forests in 2011<br>Introduction Latin America is covered by 22 per cent of the world's forest area. However, the condition of these forests is rapidly changing. Between 1990 and 2005, it experienced a 7 per cent decrease in area (64 million ha) principally as a consequence of the expansion of large-scale agriculture and cattle farming (FAO, 2009). Despite a significant increase in protected areas between 1990 and 2007 in the region, from 213 to 451 million ha, it is unlikely – espe�cially in South America – that the rate of deforestation will decrease (FAO, 2009). Add to that the change dynamic due to agricultural activities, tropical forests – in particular tropical dry forests – are at risk from the development of road infrastructure and the effects of climate change. | 86 - 87 | Prot-Adapt-Mitig-Impact | | |

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|---|---|---|---|---|---|
| Adapting to Change (2011) | During the glacial and interglacial periods, this forest advanced and retreated in successive episodes, serving as an ample shock-absorber between the dry ecosystems to the south and the humid ecosystems to the north (Pennington et al., 2004). Taking into account current characteristics such as area, state of conservation and connectivity with other ecoregions, including water basins, it plays a key role in mitigating the negative effects of climate change on the continent. | 87 - 87 | Prot-Adapt-Mitig-Impact | | |
| Adapting to Change (2011) | 3) Based on information obtained from desktop study of WH nomination files and the WCMC protected areas database. Great variation in availability and quality of data implies that the figures are indicative only and will be permanently subject to refinement. The authors welcome any information leading to improvement of the figures.<br>Annexes 101 4) 0 = Minimum threat intensity; 100 = Maximum threat intensity; for further explanation see "A Selection of WH Forest Indicators" (this volume); for graphs on each site see Annex III<br>Ecological Zone1 102 Adapting to Change – The State of Conservation of World Heritage Forests in 2011 Annex II: World Heritage Forests - Inscription and Geographical Characteristics 1) BC = Boreal coniferous forest; BM = Boreal mountain system; TempC = Temperate continental forest; TempM = Temperate mountain system; TempO = Temperate oceanic forest; SubD = Subtropical Dry Forest; SubD = Subtropical dry forest; SubH = Subtropical Humid Forest; SubM = Subtropical Mountain System; TrD = Tropical dry forest; TrM = Tropical moist deciduous forest; TrMS = Tropical mountain system; TrR = Tropical rainforest 2) A = Afrotropical; Au = Australian; I = Indomalayan; N = Neotropical; Ne = Nearctic; O = Oceanic; PE = Palaearctic East; PW = Palaearctic West<br>Annexes 103 3) Further information on IUCN categories available online: http://www.iucn.org/about/work/programmes/pa/pa_products/wcpa_categories/<br>104 Adapting to Change – The State of Conservation of World Heritage Forests in 2011 Annex II: World Heritage Forests - Inscription and Geographical Characteristics 1) BC = Boreal coniferous forest; BM = Boreal mountain system; TempC = Temperate continental forest; TempM = Temperate mountain system; TempO = Temperate oceanic forest; SubD = Subtropical Dry Forest; SubD = Subtropical dry forest; SubH = Subtropical Humid Forest; SubM = Subtropical Mountain System; TrD = Tropical dry forest; TrM = Tropical moist deciduous forest; TrMS = Tropical mountain system; TrR = Tropical rainforest 2) A = Afrotropical; Au = Australian; I = Indomalayan; N = Neotropical; Ne = Nearctic; O = Oceanic; PE = Palaearctic East; PW = Palaearctic West<br>Annexes 105 3) Further information on IUCN categories available online: http://www.iucn.org/about/work/programmes/pa/pa_products/wcpa_categories/<br>UNESCO Inscription Criteria: Cultural i. to represent a masterpiece of human creative genius; ii. to exhibit an important interchange of human values, over a span of time or within a cultural area of the world, on developments in architecture or technology, monumental arts, town-planning or landscape design; iii. to bear a unique or at least exceptional testimony to a cultural tradition or to a civilization which is living or which has disappeared; iv. to be an outstanding example of a type of building, architectural or technological ensemble or landscape which illustrates (a) significant stage(s) in human history; v. to be an outstanding example of a traditional human settlement, land-use, or sea-use which is representa�tive of a culture (or cultures), or human interaction with the environment especially when it has become vulnerable under the impact of irreversible change; vi. to be directly or tangibly associated with events or living traditions, with ideas, or with beliefs, with artistic and literary works of outstanding universal significance. (The Committee considers that this crite�rion should preferably be used in conjunction with other criteria); Natural vii. to contain superlative natural | 95 - 101 | Prot-Adapt-Mitig-Impact | INTANBILE | |
| Adapting to Change (2011) | This is why UNESCO is devoting this edition of the World Heritage Papers series to forest conservation and the green future of our planet. This publication highlights all forest areas inscribed on the UNESCO World Heritage List. To date, the List contains 104 forests, covering a total area of over 75 million hectares (750,000 sq km). Each is a unique ecosystem that provides space for cooperation in science, education, and culture and that is invaluable for the benefit of all. | 4 - 4 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Launched in 2001, UNESCO's World Heritage Forest Programme celebrates the social and cultural value of forests for local communities and conveys the extraordinary natural beauty and biological diversity of these sites. The three Rio Conventions devoted to climate change, biological diversity and combating desertification, along with the United Nations Forum on Forests, all emphasize the pressing need to manage natural resources sustainably. UNESCO works to strengthen the importance of sustainable forest manage�ment, and especially conservation, as green economy activities that contribute to the eradication of poverty. | 4 - 4 | Prot-Adapt-Mitig- | | INDG |

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|---|---|---|---|---|---|
| Adapting to Change (2011) | 3 Joint Foreword Irina Bokova Director-General of UNESCO Sha Zukang United Nations Under-Secretary�General for Economic and Social Affairs and Secretary-General of the UN Conference on Sustainable Development<br>5 T his second State of Conservation of World Heritage Forests report was timed for release during the United Nations International Year of Forests, the motto of which Celebrating Forests for People is very appropriate to the World Heritage Convention – a widely recognized United Nations convention created in large part to ensure that people, both current and future generations, could continue to celebrate and benefit from the outstanding cultural and natural diversity of our world. | 4 - 5 | Prot-Adapt-Mitig- | INTANBILE | |
| Adapting to Change (2011) | The first World Heritage forests were inscribed on the World Heritage List in 1978 (Nahanni National Park in Canada, Yellowstone National Park in the USA). As of the 35th session of the Intergovernmental World Heritage Committee in 2011, 104 World Heritage sites covering over 77 million hectares across all biogeographic realms are recognized as World Heritage forest sites – by any standard this is a huge success story for forest conservation. But recognition is only one part of the World Heritage Convention. The complementary part focuses on conservation – a more difficult task. | 5 - 5 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | The World Heritage Committee monitors the state of conservation of World Heritage sites, and over the years – as demonstrated in this publication – it has become apparent that World Heritage forests are a particularly vulnerable group of World Heritage sites. | 5 - 5 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | The FAO's Global Forest Resource Assessment for 2010 indicates that the trend for including forests in protected areas has accelerated in the last ten years, but that non�protected primary forests – those least disturbed by intensive human activity – continue to be lost at a rate of 4.2 million hectares a year. Extrapolating these trends leads us to conclude that as access to non-protected primary forests becomes ever more difficult, pressure to facilitate access to the remaining protected forests will increase. A brief review of the annual State of Conservation reports produced by the World Heritage Centre and IUCN for the World Heritage Committee reflects this reality in the wide range of threats to listed World Heritage forests. For example, illegal logging and the bushmeat trade pose grave threats to several World Heritage forests because the lands surrounding these sites have often already been depleted of such resources. | 5 - 5 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Beyond the threats that we have grown accustomed to dealing with, climate change is expected to significantly increase the complexities of protected area management in the coming years. Managers will need to redouble their efforts, not only to reduce existing threats but also to look beyond the boundaries of their protected areas so that suitable adaptation strategies may be implemented. These managers will need to develop the capacity and be given the responsibility to engage with agents of wider land use changes in order to achieve this. | 5 - 5 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Introductory Remarks Kishore Rao Director UNESCO World Heritage Centre<br>6 There is an urgent need to find ways in which the World Heritage Convention will, on the one hand, ensure the long term conservation of World Heritage forests, and on the other, encourage the replenishment and sustainable management of accessible forest resources for local communities whose access to resources have been considerably reduced. Recognizing the need to encourage synergies between conservation and development, the World Heritage Committee requested at its 34th session in 2010 that sustainable development measures be integrated into the work of the World Heritage Convention, which has resulted in the approval of an action plan to further this objective. | 5 - 6 | Prot-Adapt-Mitig- | | INDG |
| Adapting to Change (2011) | Interesting opportunities are emerging in the case of World Heritage forests. For instance, the emerging global recognition of the role of forests in capturing and storing carbon has led to the development of mechanisms designed to encourage forest conservation, sustainable forest management, and the enhancement of forest carbon stocks through the programme, Reducing Emissions from Deforestation and Forest Degradation (REDD+). | 6 - 6 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | In the early stages of development, REDD+ has the potential to compensate communi�ties involved in activities that will result in increased forest cover and better forest management. The link with the conservation of World Heritage forests in the long term is obvious, and worth exploring. | 6 - 6 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Beyond providing an overview of the state of conservation of World Heritage forests in general, this publication attempts to provide some welcome thoughts on the relation�ship between World Heritage forests and their surrounding landscapes, and on mecha�nisms that could be applied to ensure that this relationship is mutually beneficial alongside social, economic and environmental criteria. I am convinced that the World Heritage Convention can be effectively leveraged to bring about such positive contribu�tions, and I look forward to seeing tangible results on the ground. | 6 - 6 | Prot-Adapt-Mitig- | INTANBILE | |

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| Adapting to Change (2011) | Kishore Rao Director UNESCO World Heritage Centre Adapting to Change – The State of Conservation of World Heritage Forests in 2011<br>7 While many forests predate human existence on earth, forest history is – at its core – about the changing relationships between people and forests, and was the reason behind the choice of the International Year of Forests to celebrate 'Forests for People'. | 6 - 7 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | UNESCO World Heritage sites provide a perfect example of how forest conservation can help improve our planet for future generations. With the recent World Heritage designations, sites such as the Ogasawara Islands (Japan) have brought the number of World Heritage Forest sites to 104, putting UNESCO in a unique position to protect some of the world's most precious forests. | 7 - 7 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | World Heritage forests are not immune to these inexorable forces of change, posing a constant challenge to those seeking to maintain the rigidly defined OUV for which these forests were added to the World Heritage List, while simultaneously incorporating the management flexibility required by changing conditions. | 11 - 11 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | 12 11 Adapting to Change – The State of Conservation of World Heritage Forests in 2011 New Challenges for World Heritage Forests by Jeffrey A. McNeely Senior Science Advisor, IUCN<br>The changes to forests are far greater than simply an aesthetic issue of interest, primarily to conservationists. In fact, every person in the world is affected by what is happening to forests, even though many remain blissfully unaware of their dependence. For example, the forests of the Amazon basin are often considered 'the lungs of the planet' because of the oxygen they produce through photosynthesis. But in two of the past five years, drought conditions have converted the Amazon into a net consumer of oxygen and producer of carbon dioxide (Lewis et al., 2011). When droughts or fires hit forests, even World Heritage status cannot prevent them from producing more of the greenhouse gases that can accel�erate further climate change. | 11 - 12 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | While World Heritage forests may have been designed and managed to be less vulnerable to fragmentation caused by humans, this protection is not always perma�nent. For example, in 2009 New Zealand's Mount Aspiring National Park (part of the South West New Zealand World Heritage Area) was threatened with losing 20 per cent of its area to open up mining opportunities (Haggart, 2009). | 12 - 12 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Examples of similar approaches on the World Heritage forests list include the Gondwana Rainforests of Australia, the Wet Tropics of Queensland, Brazil's Southeast Atlantic Forest Reserves and Central Amazon Conservation Complex, among others. But much more could be done, perhaps beginning with linking the World Heritage forests of Central America (Panama's Darien National Park, the Panama/Costa Rica transboundary Talamanca Range�La Amistad Reserves, Guatemala's Tikal National Park, and Río Plátano Biosphere Reserve in Honduras) with other forested areas that do not meet World Heritage criteria by themselves, but can contribute to the OUV of an entire landscape. World Heritage could then be seen as the centrepiece of the Mesoamerican Biological Corridor (Muller and Patry, this volume). The Yellowstone to Yukon corridor could find ways to link Yellowstone to Kluane/Wrangell St. Elias/Glacier Bay/Tatsheshin-Alsek, using World Heritage properties – like beads in a natural necklace: Glacier, Waterton, Nahanni, the Canadian Rocky Mountain Parks, and Wood Buffalo would be substantial jewels in such a necklace. Given that such connectivity plays a role in assuring the OUV of these sites, the World Heritage Committee might be interested in playing a more active role in helping bring such systems about. | 12 - 12 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Another form of connectivity is also worth exploring: the vertical movement on mountains. Already, many World Heritage forests are cloaking mountains, and the idea is State of Conservation of World Heritage Forests in 2011 13 1<br>that species responding to climate change will have rela�tively short geographic distances to move, so plants and animals can more easily change their elevational distri�bution in order to remain in a sort of equilibrium with the climate (Bush et al., 2004); lower elevation areas could be added as a sort of buffer zone for possible future expan�sion. World Heritage Mountain Forests that could form the basis of such an approach include the Greater Blue Mountains (Australia), Three Parallel Rivers of Yunnan (China), Los Katios (Colombia), Sangay (Ecuador), Nanda Devi and Valley of Flowers (India), Lorentz (Indonesia), Mount Kenya (Kenya), and Kinabalu (Malaysia). A research and monitoring programme based on World Heritage Mountain Forests could be highly productive, with useful comparisons among different geographical variables. | 12 - 13 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | On the other hand, World Heritage can also help to address this problem, especially when neighbouring coun�tries are also involved in the conservation of adjacent sites. | 13 - 13 | Prot-Adapt-Mitig- | | |

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| Adapting to Change (2011) | Conclusion: How World Heritage forests can be the catalyst for forest conservation The International Year of Forests has been established with the objective of drawing the world's attention to these critically important ecosystems and their multiple values for humanity. The hope is that this attention will in turn lead to greater protection for the remaining forested areas of our planet. World Heritage forests can play a crit�ical role in this global initiative, as the papers in this publi�cation demonstrate. As forests recognized by govern�ments to be of outstanding universal value, they can open the minds of governments, corporations, and the public to the magnificence of what remains of our green planet. | 14 - 14 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | • Make best use of the management tools available to World Heritage forests at all levels, from the most humble forest guard up to the World Heritage Committee. Through the long-term monitoring of World Heritage forests, management responses can be calibrated to respond to emerging needs, which might even include changing some boundaries, linking World Heritage forests through corridors of suitable habitat, and managing natural forces such as fires, disease outbreaks, and senescence. Perhaps more importantly, management techniques developed in World Heritage forests could be applied to other forests to deal with increasing human pressures, using techniques such as the certification of sustainable harvesting (Newsom, this volume), the use of new technologies to maintain genetic diversity, controlling the spread of invasive alien species, and dealing with the anthropogenic spread of pathogens. | 14 - 14 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | The bottom line: eternal vigilance, powerful partnerships, adaptive management, and strong public support will provide the best chance for a healthy future for World Heritage forests. | 14 - 14 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | At its 35th session, the Committee recently decided to extend the Primeval Beech Forests of the Carpathians, originally inscribed in 2007, with a surface area of 29,279 ha. The site now includes the Ancient Beech Forests of Germany, resulting in a total coverage of 33,670 ha in three countries. Forty per cent of World Heritage forests are less than 100,000 hectares in size. Seven are even less than 10,000 hectares. Generally speaking, the smaller the size, the greater the need to ensure effective management in order that the capacity to respond to threats is in place. States Parties should constantly be encouraged to nominate larger forests, or to increase the size of existing World Heritage forests wherever possible. Alternatively, the management of smaller World Heritage sites should receive adequate support and attention in order to ensure that their OUV is fully conserved over time. | 16 - 17 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Relative proportion of 'Danger List' sites that are World Heritage forests When conditions are such that a World Heritage site is faced with threats that may irreparably harm its OUV, the World Heritage Committee may inscribe the site on the List of World Heritage in Danger as a way to draw national and international attention to the site's conservation needs. | 19 - 19 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | A site is removed from the list once the Committee is satis�fied that its OUV is no longer under threat. Measuring the proportion of World Heritage forests that are on the Danger List over time provides an indication of the overall trend in the state of conservation – and therefore vulnera�bility – of World Heritage forests. | 19 - 19 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Reporting Trend The Reporting Trend (formerly called the 'Threat Intensity Coefficient') is a function of the number of times the World Heritage Committee reviews the state of conserva�tion of a particular site in the preceding fifteen years, together with the relative distance in time the review has taken place. Thus, if the World Heritage Committee reviewed a site for a few years running, but 10–15 years ago, the trend value will be very low and dropping, this would indicate that the issue in question occurred in the past but was no longer raising concerns. However, a review of a site over the past three to four years will reveal a steep increase in the Reporting Trend value, indicating a current concern that remains an issue. A value of 0 indi�cates the World Heritage Committee had not reviewed the site in the past fifteen years, and a value of 100 indicates that the Committee had studied the state of conservation of the site for each of the past fifteen years. The Reporting Trend values for individual World Heritage forests can be found in Annex III of this publication. | 19 - 19 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | World Heritage sites in danger are annually reviewed by the World Heritage Committee. While figure 5 provides an indication of the relative proportion of World Heritage forest sites in danger, figure 6 provides a broader reading of the state of conservation reviewing trends by the World Heritage Committee for all World Heritage forest sites, regardless of whether or not they are on the List of World Heritage sites in Danger. As a result, in contrast to figure 5, which indicates a decline in the proportion of World Heritage forest sites on the Danger List between 1999 and 2005, figure 6 indicates a near constant increase in the level of attention granted by the World Heritage Committee on the state of conservation of World Heritage forest sites. | 20 - 20 | Prot-Adapt-Mitig- | | |

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| Adapting to Change (2011) | With regard to figure 6, it is clear that World Heritage  forest sites have almost consistently drawn increasing  attention from the World Heritage Committee in its  annual deliberations on the State of Conservation of  World Heritage forest sites since 2002. This trend, if not  reversed, would indicate increasing conservation concerns  for World Heritage forest sites as a whole. | 20 - 20 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Conclusion  The indicators noted here, combined with those presented  in the 2007 World Heritage Centre report, help improve  the understanding of the World Heritage Convention with  regard to forest conservation worldwide, as well as  providing forest conservation stakeholders a good first quantitative impression on the state of conservation trends  for these forests. | 20 - 20 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Collectively, World Heritage forests make a very significant  contribution to forest conservation at the global level; as  of 2006, 13.3 per cent of all IUCN category I-IV protected  forests were recognized under the World Heritage  Convention (UNESCO, 2007). These forests are found to  be relatively well distributed among the major biogeo�graphic realms of the planet, with 60 per cent over  100,000 ha in size, indicating that the network of World Heritage forests largely consists of what should be fairly  resilient forests that are representative of the diversity of  the world's forest ecosystems. | 20 - 20 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | However, the indicators do point to some concerns  regarding the trends in their state of conservation. For  example, World Heritage forests are proportionately over�represented on the List of World Heritage in Danger, and  they are also steadily attracting more attention over time  from the World Heritage Committee in their deliberations  over the state of conservation of World Heritage sites. | 20 - 20 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Both these indicators suggest that the conservation of  World Heritage forests is increasingly difficult. Further  research would be required to investigate the nature of  the threats being considered by the World Heritage  Committee so as to better define the factors contributing  to these trends. | 20 - 20 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Some of the climate related change in plant and animal  communities are now apparent (i.e. along the edge of a  forest-grassland transition) and others are yet too subtle for  us to detect. The changes will become more apparent in  the future, and the rate of climate change suggests that  24  2 Adapting to Change – The State of Conservation of World Heritage Forests in 2011  Climate Change and World Heritage Forests   by Jim Perry  University of Minnesota landscape changes will accelerate. The most likely places to  detect changes will be those that are climatically marginal  (i.e. transitional areas between forest types or areas where a  forest's character is unusual for the region – perhaps having  tree cover that is characteristic of a wetter or drier region). | 22 - 23 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Some modeling efforts accept the average prediction  among models as the best answer available, and use that  in planning future management. An alternative is to  examine variance among models (i.e. standard deviation  among models, over the mean of model predictions) as an  estimate of uncertainty. If most models predict similar  conditions, that ratio will be low and one can be relatively  confident in predicted conditions. If that ratio is large,  there is less agreement among models and one should  have less confidence in the predictions. Uncertainty plays a  relatively small role at a given site. However, society has a  relatively fixed amount to invest in adaptive management  of World Heritage forests. Uncertainty around predicted  future conditions should influence where those resources  are invested. For example, sites whose climate change  predictions are more certain should receive higher priority. | 23 - 23 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Fortunately, other tools exist to help site managers get a  better idea of the climate changes that might occur at  their site, offering directions for adaptation initiatives. | 24 - 24 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | The information required for a given site will always be  contextual; a review of the variables that drive vulnerability  will allow a site manager to identify the variables most  appropriate for his/her site. Many of those data can be  collected at coarse spatial scales (i.e. for assessing a site in  its surrounding landscape) from remote sensing data such  as Google Earth. Geographic Information System (GIS) files  of the site will be an invaluable way to identify finer scale  spatial pattern, to track and express observed changes in  pattern, and to plan management actions (i.e. collabora�tive management with an adjacent land unit). Data avail�ability for GIS applications will vary widely among sites. | 24 - 24 | Prot-Adapt-Mitig- | | |

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| Adapting to Change (2011) | The HII is calculated for a designated area (i.e. a site itself or a site in its surrounding landscape). The HII can express current and anticipated anthropogenic influences on a site and can guide a site manager in developing proactive management strategies. For example, a site in a land�scape with a high HII might anticipate that climate changes will cause increased incursion on the site. | 24 - 24 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Certainly, the more sensitive forest sites and their compo�nents (i.e. sea level forests, forest-grassland transitions) are noticeably changing. However, many World Heritage forests are large, relatively uniform tracts. Such systems may be strongly resistant to climate change and may deserve increased levels of attention and protection for just that reason. | 25 - 25 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | 28 2 Adapting to Change – The State of Conservation of World Heritage Forests in 2011<br>Connectivity and the maintenance of biodiversity in World Heritage forests Many different properties of forest reserves, including their size, continuity or fragmentation, and the degree to which they are connected to other forest areas, affect their usefulness for preserving biodiversity. Connectivity and its inverse – isolation – measure the extent to which a land�scape facilitates or impedes the movement of organisms between habitat patches. It is an important determinant of biodiversity within forests because it strongly influences the rates and patterns of species survival and dispersal, affecting many ecological processes. The ability to move across a region, exploiting resources that vary in space and time, is a fundamental requirement for survival in many species; connectivity between habitat patches facilitates such movement and is often an important contributor to the long-term persistence of such species, and others that depend on them. | 26 - 27 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Whereas the primary focus of the REDD+ mechanism is the creation of incentives for reducing CO2 emissions and enhancing forest carbon stocks in developing coun�tries, it bears great potential to promote actions that contribute to the conservation targets of the Convention on Biological Diversity (CBD) and of the World Heritage Convention (WHC) (SCBD, 2009; von Scheliha et al., 2009; Pistorius et al. 2010). | 30 - 30 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | However, these potential additional benefits will not auto�matically be achieved because REDD+ is designed with a quantitative focus on carbon (Brown et al., 2009; Long, 2009; Pistorius et al., 2010). Although the latest REDD+ negotiation text calls for a safeguard to prevent the conversion of natural forests 2, the UNFCCC forest defini�tion in itself does not distinguish between natural forest and forest plantations 3 and thus is a loophole for manage�ment activities that are harmful to forest biodiversity. The same holds true for the sustainable management of forests (SMF), which is promoted by the UNFCCC4 but lacks an adequate definition (Pistorius et al., 2010). | 30 - 30 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Although the biodiversity indicators used to account for positive net-benefits of the projects –as required by the standards – certainly have some shortcomings as their choice is not necessarily based on sound biologically and ecologically considerations (Entenmann, 2010), they exem�plify a practical compromise between ecological require�ments and financial and time constraints. Furthermore, the monitoring activities carried out in REDD+ projects, in Adapting to changes 33 2 5. Standard of the Carbon, Community and Biodiversity Association (CCBA): http://www.climate-standards.org/ 6. For more information: http://planvivo.org Box 1: REDD+ activities in or adjacent to World Heritage forest sites The tropical biome comprises the biggest part of World Heritage forest sites, both in terms of numbers and area, and the total area of World Heritage forest sites increased strongly in the tropics from 1997 to 2006 (Patry et al. 2007). At the same time, there has also been a growing number of conservation activities that apply REDD+ components in tropical forests in or adjacent to World Heritage forest sites. | 31 - 31 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | An example for REDD+ activities emerging adjacent to World Heritage forest sites is a forest carbon programme in the Maya Biosphere Reserve in Guatemala, which is a mosaic landscape of PAs includ�ing community managed forest concessions and the World Heritage forest site Tikal National Park. It is intended to reduce deforestation by using Conservation Agreements and strengthening of community management (Harvey et al. 2010). | 31 - 31 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Connectivity Increasing isolation of PAs has become a big problem over recent decades (DeFries et al., 2005) and is also a great chal�lenge regarding World Heritage forest sites (Patry, 2007). In response, the CBD Programme of Work on Protected Areas 7 adopted the mitigation of ecological isolation and fragmen�tation of PAs as one of its goals. Furthering ecological connectivity is also a recognized climate change adaptation strategy (Thompson et al., 2009). | 32 - 32 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Kasigau Corridor REDD Project, Kenya The Kasigau Corridor REDD Project is located between the Tsavo East National Park and the Tsavo West National Park in Southeast Kenya (Figure 1). REDD+ activities include the protection of the existing carbon stock in the area under threat i.e. by firewood extraction and charcoal production, and some reforestation activities using native trees. | 32 - 32 | Prot-Adapt-Mitig- | | |

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| Adapting to Change (2011) | According to the Project Design Proposal (WildlifeWorks, 2008; SCS, 2009), the project intends to create a corridor between the two national parks in order to facilitate large mammal migration and to support the conservation of the wildlife and flora within a larger area (Figure 1). | 32 - 32 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Consequently, developing and monitoring indicators for poaching is one central aspect in the monitoring plan of the project. This case highlights that it is not only neces�sary to create a physical connection between parks to facilitate migration, but also to reduce threats. In addition, the corridor needs to meet the ecological requirements of the target species in order to fulfil its connecting function (Fischer et al., 2006; Fischer and Lindenmayer 2007). In this regard, it is important to know the home ranges of the species as the conservation activities aim to ensure that the animals can actually use the corridors. | 33 - 33 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Manú World Heritage Forest Site and National Park, Peru Another example of how REDD+ can be an instrument to contribute to the conservation and connectivity of PAs are the REDD+ activities that are currently being developed in the Madre de Dios region of Peru. These REDD+ activities involve different stakeholder groups and land use/ownership categories like forestry concessions, brazil nut concessions, indigenous communities, national reserves, and private conservation concessions; they take place within or in direct vicinity to PAs in the greater area around the World Heritage forest site Manú National Park (Figure 2) and within the Vilcabamba-Amboró Conservation Corridor (CEPF, 2000). | 33 - 33 | Prot-Adapt-Mitig- | | INDG |
| Adapting to Change (2011) | A REDD+ project is currently being implemented in the Private Conservation Concession Los Amigos' (Figure 2, d) with the intention of generating financial means to partly cover the costs of investigating, monitoring and control�ling the area. The concession occupies the watershed of the Los Amigos River and reaches to the Manú River, which enters into the Manú World Heritage forest site. | 33 - 33 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Consequently, the concession protects not only the upstream area of the Watershed of the Los Amigos River, but also to some extent the Manú area, since from the concession it is possible to monitor illegal loggers entering or leaving the World Heritage forest site via the Manú River. So, while REDD+ was not the first incentive to initiate the private conservation concessions, the financial means generated through REDD+ can now contribute to securing the World Heritage forest site. | 33 - 33 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Rainforests of Atsinanana, Madagascar There are currently some efforts to increase the connec�tivity of a series of World Heritage forest sites in Madagascar, connecting the rainforests of Atsinanana consisting of six non-continuous national parks: Marojejy National Park, Masoala National Park, Zahamena National Park, Ranomafana National Park, Andringitra National Park and Andohahela National Park. The Mantadia Corridor Reforestation Initiative, initiated by Conservation International, employs REDD+ and reforestation activities in an area adjacent to the south of Zahamena National Park. This includes the establishment of a new PA that links Zahamena to Mantadia National Park. The Corridor Ankeniheny-Zahamena REDD+ initiative (CAZ) is an area of 425,000 ha and aims to create new PAs that will be zoned into both strict protection areas and areas under commu�nity sustainable management (Harvey et al., 2010). | 34 - 34 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Another conservation project with REDD+ elements, the Fandriana-Vondrozo Corridor Project, is adjacent to the Ranomafana National Park and connects to the Andringitra National Park and Ivohibe Special Reserve. It covers an area of 240,000 ha and has a similar method�ology as CAZ. Another REDD+ initiative, the Makira project, implemented by the Wildlife Conservation Society with support from Conservation International, is adjacent to Masoala National Park (Holmes et al., 2008). | 34 - 34 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | These include improved management effectiveness, espe�cially if there is a high historical deforestation rate in the area (Doyle, 2009), the creation of financial incentives for the long-term designation of PAs, and restoration activities in degraded protected areas. | 34 - 34 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Moreover, a scientifically designed, comprehensive and ecologically connected network of representative PAs can be regarded as a viable climate change adaptation strategy (Margules and Pressey 2000; Thompson et al., 2009). | 35 - 35 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Implementation of REDD+ projects outside PAs or the establishment of new PAs is often restricted by land use conflicts and the high transaction costs of coming to terms with the different land users. Therefore legislative arrange�ments regarding REDD+ have to be made in order to ensure that the location of REDD+ activities is not just determined by the legal and socioeconomic setting, but that they can also be implemented in areas that are strate�gically apt in terms of conservation and connectivity of World Heritage forest sites and other PAs. | 35 - 35 | Prot-Adapt-Mitig- | | |

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| Adapting to Change (2011) | Further information  This study was carried out in the framework of the  research project, The Protection of Forests under Global  Biodiversity and Climate Policy, hosted by the Institute for  Landscape Management and the Institute of Forest and  Environmental Policy of Freiburg University, Germany. The  project is financially supported by the German Federal  Agency for Nature Conservation (BfN) with funds from the  German Federal Ministry for the Environment, Nature  Conservation and Nuclear Safety (BMU).10  References  Bangladesh Forest Department. 2010. Bangladesh develops forest carbon financing opportunities. Bangladesh Forest Department and US-AID. | 35 - 35 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | The mechanism would channel funds from industrialized  nations and industries to forested developing countries   in order to support conservation interventions that reduce  forest based greenhouse gas emissions reductions and  increase the sequestration of greenhouse gas from the  atmosphere. The proposals are unique because they  involve performance based payments—payments would  only be delivered if emissions reductions were measured,  reported and verified. | 37 - 37 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | The mechanism is still under development but will likely  involve the transfer of international funds (potentially from  a combination of carbon markets, donors and taxes) to  participating governments. Governments would then be  responsible for national carbon emissions monitoring and  accounting, and for a country-wide programme of forest  emissions reduction and sequestration. Interventions would  be based on national priorities and the opportunity costs   of competing land uses (i.e. agriculture, development), but  would also likely include enabling conservation policies,  protected area establishment and conservation conces�sions, and support and funds disbursement to local forest  managers—potentially including World Heritage forests. | 37 - 37 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | The process of designating a World Heritage forest  considers a wide range of factors but has not traditionally  addressed carbon stocks (process reviewed in Patry,  2007a). Nevertheless, forest carbon storage represents a  new global conservation priority that merits increased  consideration. In the face of rapid REDD+ policy develop�ment and unprecedented donor funding, there is a need  to assess the opportunities and limitations of integrating World Heritage forests into future forest carbon emissions  mitigation strategies; it cannot be assumed that they will  be automatically included into these emissions mitigation  strategies. We identify leading issues for World Heritage  forest managers interested in upcoming REDD+ policies. | 37 - 37 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Potential for additionality  Additionality is a major concept in REDD+ planning—  whether activities rewarded by a future REDD+ mechanism  represent an improvement over a 'business as usual'  scenario. It is uncertain whether the financing of existing  protected areas represent significant gains for emissions  mitigations. Future REDD+ initiatives are likely to maximize  resources by directing funds towards countries, forests and  sites with the greatest emissions mitigation potentials at  the lowest costs. As such, there are some likely limitations  to integrating existing World Heritage forests into a future  REDD+ mechanism. | 37 - 37 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Even so, REDD+ financial resources could be used to  improve the management of protected areas that have  historically faced encroachment (Clark, 2008; Oestreicher  et al., 2009; Scharleman et al., 2010; Rickets et al., 2010). | 37 - 37 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Potential for cost efficient emissions  reductions  There is a need to consider the cost efficiency of emissions  mitigation achieved through protected areas relative to  other REDD+ emissions mitigation approaches, such as  reforestation, carbon stock enhancement and sustainable  forest management. | 37 - 37 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Adapting to changes  39  2  Integrating World Heritage Forests into a Future REDD+  Mechanism  by Jacob Phelps and Edward L. Webb  Dept. Biological Sciences, National University of Singapore<br>Protecting threatened, high-carbon density forests is  generally considered among the most cost efficient forest  based emissions mitigation strategy (i.e. Rickets et al.,  2010). This approach requires comparatively limited inputs  and can often benefit from economies of scale (Oestreicher  et al., 2009). Large protected areas may thus be especially  attractive for cost-effective REDD+ interventions. | 37 - 38 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | For example, some countries and regions may specifically  seek REDD+ interventions that deliver not only emissions  reductions, but also livelihood opportunities and additional  biodiversity conservation that involve increased costs. | 38 - 38 | Prot-Adapt-Mitig- | | |

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| Adapting to Change (2011) | The strengths of World Heritage forests Even where World Heritage sites do not have the most cost efficient emissions mitigation strategy, there are still opportunities for REDD+ through World Heritage forests to capture voluntary investment. To date, corporate social responsibility has been a significant motivator of carbon credit purchases (EcoSecurities et al., 2010; Hamilton et al., 2010), and World Heritage forests have the potential to offer charismatic REDD+ projects with substantial addi�tional biodiversity co-benefits. | 38 - 38 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Emissions mitigation efforts associated with World Heritage forests can also provide valuable guarantees for investors. Well managed protected areas are familiar instruments for the effective conservation of terrestrial carbon stocks (Clark, 2008; Oestreicher et al., 2009; Scharleman et al., 2010). In comparison with other types of prospective REDD+ contracts, such as with individual landholders, World Heritage forests generally benefit from clear tenure, and represent long-term conservation commitments. These factors are important in ensuring permanence emissions reductions that are highly valued within REDD+ contracts. | 38 - 38 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Many World Heritage forests and surrounding landscapes have also been the sites of monitoring and research, with comparatively large amounts of information about their biodiversity, forest types and associated threats, as well as experience with protected areas management and inter�national reporting. This background may provide some sites with a head start for establishing baselines and identi�fying conservation interventions for their surrounding landscapes. They may also provide important lessons learned for national level REDD+ strategy development and REDD+ development in protected areas. | 38 - 38 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Scope for diverse tenure arrangements Yet there remains considerable debate regarding whether traditional protected areas are most the effective and effi�cient approaches to conservation in all situations when compared with community based conservation and other conservation arrangements (Adams et al., 2004). While initial research highlights the importance for REDD+ initia�tives to address local needs and engage local populations (i.e., Oestreicher et al., 2009), it remains uncertain which land tenure and governance arrangements will yield optimal REDD+ outcomes (Clark et al., 2008; Chhatre and Agrawal, 2009; Rickets et al., 2010). | 38 - 38 | Prot-Adapt-Mitig- | | INDG |
| Adapting to Change (2011) | REDD+ policies may combine incentives for traditional protected areas with incentives and technical support for community based and co-managed protected areas, and voluntary financial incentives for private landholders and concessionaires (Agrawal et al., 2008). They may also allow for strict conservation areas alongside sites with multiple use objectives, including sustainable management of forests. The challenges, effectiveness, efficiency and trans�action costs associated with REDD+ on different tenure instruments are not well understood and will need to be assessed as World Heritage forests are further integrated into the broader landscape through REDD+. | 38 - 38 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Adapting to changes 41 2<br>The majority of World Heritage forests (66 sites) are in tropical and subtropical developing countries, covering an area of nearly 43 million hectares. These forests protect sizeable stores of terrestrial carbon, important to global climate regulation. The continued and enhanced protection of these sites is potentially relevant to a future REDD+ climate change mitigation mechanism under development through the United Nations Framework Convention on Climate Change (UNFCCC). The World Heritage Committee has vested interests in these large scale, transformational policies as they would affect World Heritage forests across the globe. This paper reviews the status of REDD+ policy development and highlights issues of interest to the World Heritage community, including possible contributions to the REDD+ policy debate. | 39 - 40 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Through a REDD+ mechanism, industrialized countries and carbon emitting industries would provide developing countries with financial incentives to reduce forest based greenhouse gas emissions and increase forest-based removal of greenhouse gases from the atmosphere. A REDD+ mechanism would reward a range of conservation interventions: • Reduced deforestation • Reduced forest degradation • Conservation of existing forest carbon stocks • Enhancement of forest carbon stocks (i.e. through tree planting) • Sustainable management of forests (i.e. selective cutting and replanting) The UNFCCC has entered its sixth year of negotiations on the design of a future REDD+ mechanism. Despite the prolonged process, recent pledges for billions of dollars in donor support have spurred rapid REDD+ policy develop�ments both within and outside the UNFCCC. Nearly every one of the large, international non-governmental organi�zations has developed a REDD+ programme. Dozens of REDD+ pilot projects have emerged, and more than two dozen developing countries are in the process of devel�oping REDD+ national strategies. The engagement of World Heritage forests with a future REDD+ mechanism would promise harmonization with broader environmental conservation goals, and could offer a novel and large source of funding for forest managers. Yet there are a number of remaining, unresolved policy and methodolog�ical issues. | 40 - 40 | Prot-Adapt-Mitig- | | |

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| Adapting to Change (2011) | The UNFCCC process To date, no formal concrete REDD+ mechanism has been established through the UNFCCC. Nevertheless, the UNFCCC 16th Conference of Parties (COP16) held in Cancun, Mexico, in late 2010 demonstrated considerable political support for REDD+. In fact, REDD+ is one of the areas of broadest consensus within the UNFCCC climate negotiations (UNFCCC, 2010). The resulting Cancun Agreement defined a broad scope for REDD+, urging developing country Parties not only to reduce deforestation and forest degradation, but also to plan for the conserva�tion and enhancement of existing forest carbon stocks and the sustainable management of forests. While this broad�ened scope increased opportunities for participation, a remaining challenge is to specifically define the land uses that would be rewarded through a future REDD+ mecha�nism. The Cancun Agreements further ensured continued REDD+ negotiations among the UNFCCC Parties and early development of REDD+ pilot projects, setting guidelines for future policy development (including rudimentary safe�guards), and setting ambitious pledges for donor finance. | 40 - 40 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | These efforts include dozens of pilot projects, which are reforming forest governance strategies, pioneering forest and carbon inventory accounting and monitoring tech�niques, and developing strategies to identify and limit the drivers of deforestation and degradation. As such, oppor�tunities to engage in REDD+ are not limited to the official 42 2 Adapting to Change – The State of Conservation of World Heritage Forests in 2011 What World Heritage Can Offer REDD+ Policy Development by Jacob Phelps and Edward L. Webb Dept. Biological Sciences, National University of Singapore UN process or policy development. There is also a wide�spread need for pilot initiatives and best practices in reducing deforestation and forest degradation, including through protected areas management. | 40 - 41 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Despite the emergence of an international REDD+ frame�work, the independent development of national REDD+ strategies and the identification of nationally appropriate emissions mitigation strategies suggest that approaches on the ground may vary considerably. The role of protected areas and landscape level planning in reducing forest based emissions is also likely to vary based on national priorities, resources and leadership. External donor support and Party commitments to existing international agree�ments are also likely to be pivotal in determining countries' REDD+ strategies. | 41 - 41 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | REDD+ is principally concerned with carbon sequestration and the non-release of forest carbon, rather than with forest conservation in and of itself. While protecting forests generally equates to positive biodiversity outcomes, ensuring, measuring, monitoring and reporting additional biodiversity and social co-benefits involves increased costs. | 41 - 41 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | While the UNFCCC promotes co-benefits, these additional costs will likely be externalized. The financial and technical support required to deliver co-benefits will likely come from donors and voluntary buyers that favour REDD+ interventions with multiple benefits. However, it is uncer�tain whether a future REDD+ mechanism will recruit adequate voluntary and donor resources to deliver addi�tional co-benefits (Phelps et al., 2011). As a result, some policy makers, including the CBD Secretariat, are advo�cating for a REDD+ mechanism that integrates not only safeguards, but also internalizes the costs of delivering additional livelihood and biodiversity co-benefits (i.e. CBD and GIZ, 2011). The co-benefits debate, in parallel with negotiations on REDD+ safeguards, will largely dictate the conservation potential of REDD+ interventions and influ�ence the involvement of World Heritage forests. | 41 - 41 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | The status of REDD+ funding REDD+ offers unprecedented resources for forest conser�vation. During the mid-1990s, annual spending on protected areas in developing countries totaled approxi�mately US$600 million (James et al., 2001). In contrast, donors have already pledged over US$4 billion in finance for early REDD+ planning in tropical developing coun�tries, most by 2012 (Ballesteros et al., 2010). Investments could grow considerably, as the estimated annual cost of reducing tropical deforestation by 50 per cent is between US$12–35 billion (compiled in CI et al., 2010). The recent establishment of the UN Green Climate Fund, with a target of providing US$100 million per year for climate change mitigation and adaptation in developing coun�tries, including support for REDD+, suggests that greater funding is forthcoming (UNFCCC, 2010). | 41 - 41 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | • There are still relatively few international guidelines for REDD+ development. The Committee could help to provide international statutory incentives for ensuring that Member States implement REDD+ within the context of landscape level management in a way that enhances protected area networks, and has clear safeguards. | 42 - 42 | Prot-Adapt-Mitig- | | |

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| Adapting to Change (2011) | Possible national-level engagement As Member States develop National REDD+ Strategies, the World Heritage Centre is positioned not only to provide general guidelines, but also technical support to help ensure integration of World Heritage forests, best practices and landscape level management. The broader World Heritage community has also designed and managed successful protected area networks, identified drivers of deforestation and degradation, and designed conserva�tion interventions. These experiences may feed into national level REDD+ planning efforts. | 42 - 42 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | During a period when a great number of conservation agencies are jockeying for position within the REDD+ process, the World Heritage Community is pressed to iden�tify its opportunities, responsibilities and capacity for engaging in global and domestic REDD+ policy formulation. | 42 - 42 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | http://www.cbd.int/doc/publications/for-redd-en.pdf Conservation International, Environmental Defense Fund, Natural Resources Defense Council, Rainforest Alliance, The Nature Conservancy, Union of Concerned Scientists, Wildlife Conservation Society, Woods Hole Research Center. 2010. Financing Options for REDD. Washington, D.C. Conservation International. | 42 - 42 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | For forestry operations located within the buffer area of a World Heritage site, there are many elements of the FSC standards that, when implemented, could improve the ability of the site to function as an intact and robust ecosystem. These include requirements that FSC-certified forestry operations identify and conserve High Conservation Value Forests (HCVFs) and habitats for threatened and endangered species, and include having systems in place to prevent fires and the movement of invasive species, paying workers fairly, and ensuring that local communities benefit from employment and access to the forest for cultural practices and the harvesting of non-timber forest products. These sustainable forestry practices, within a landscape matrix, can also serve as an important link between multiple protected areas. | 44 - 44 | Prot-Adapt-Mitig- | INTANBILE | INDG |
| Adapting to Change (2011) | Río Plátano Biosphere Reserve At 500,000 hectares in size, the Río Plátano reserve is the largest remaining undisturbed tropical rainforest in Honduras, and one of the few remaining humid tropical rainforests in Central America. The majority of the area is covered by mature broadleaf forests, with pine savannahs, mangroves, swamp forest and hardwood gallery forest found along the Plátano river and its tributaries. Over 2,000 indigenous people have preserved their traditional way of life within this mountainous landscape.12 This World Heritage site is under threat from agricultural expansion into the southern and western sides of the reserve and illegal logging for species such as mahogany (Swietenia macrophylla). Wildlife within the reserve is under threat from uncontrolled commercial hunting and the introduction of exotic species.13 A lack of park staff has been cited as compounding the problem.14 Two RA/FSC-certified forestry operations are located within or adjacent to the Río Plátano Biosphere Reserve (RPBR). The first is UNICAF-BRP (Union of Agro-Forestry Cooperatives of the Río Plátano Biosphere Reserve) an organization that was created in 2008 with the goal of sustainable management and the sale of timber and non-timber forest products, environmental services such as carbon retention and sequestration, ecotourism and others. The group is composed of five FSC-certified oper�ations, each managing its own forest resources within the RPBR's buffer and cultural zone. | 46 - 46 | Prot-Adapt-Mitig- | | INDG |
| Adapting to Change (2011) | Afterwards, the Amur branch of WWF-Russia, aided with the identification and mapping of the key habitats, biotopes and High Conservation Value Forests, developed an ecological monitoring system and held training courses with company staff. | 49 - 49 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Corrective Action Requests related to the seven categories we examined mainly centred on the identification, mapping and conservation of High Conservation Value Forests, and potential habitats of rare and endangered plant and animal species. | 49 - 49 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | All four RA/FSC-certified operations were assessed between May 2001 and December 2003 and have been certified since. All combined, they were issued 126 major CARs and 24 minor CARs 23. Many of these CARs required improved assessment and protection of HCVFs, as well as the safeguarding of rare, threatened and endangered species. One operation was required to map its members' conservation areas, and adjust or add areas to the conser�vation zone to fill gaps and improve landscape level conservation. Another operation was required to create corridors for the movement of rare, threatened and endangered species. One CAR was issued that required training on firefighting, and the acquisition of firefighting equipment. | 50 - 50 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Corrective Action Requests that addressed worker and community issues included the requirement that all workers have access to social security benefits and first aid kits that are adequately stocked with supplies and medi�cine. Local communities will also benefit from the require�ment that chicleros and xateros – the men and women who harvest chicle and xate – are consulted with, and their opinions incorporated into forest management plans. | 50 - 50 | Prot-Adapt-Mitig- | | |

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| Adapting to Change (2011) | Based on this analysis, the future potential for forest certi�fication to enhance the functionality and integrity of World Heritage sites seems high. By explicitly targeting the areas around World Heritage sites and other protected areas for RA/FSC certification, the benefits of certified forestry will likely extend beyond the operation's bound�aries and into nearby forests and communities.<br>Most frameworks and initiatives that seek the conserva�tion of natural and cultural landscapes recognize the complexities and challenges involved, namely, the need to reduce the threats to natural habitats while promoting and sustaining the livelihoods of people living within such landscapes. In seeking to deconstruct these complexities, we are forced to resolve issues such as how to define forest, how to manage forests under dynamic conditions with incomplete system knowledge, and how to deliver the benefits of conservation in an equitable manner. | 51 - 52 | Prot-Adapt-Mitig- | INTANBILE | |
| Adapting to Change (2011) | These issues are neither simple, nor can they be properly resolved by any single disciplinary approach. Indeed, recognition of this by, for example, the World Heritage Convention and the Convention on Biological Diversity (see for instance, the report on World Heritage and Sustainable Development), has led to the promotion of ecosystem management approaches that seek, among other things, to promote equity and benefit-sharing though the integration of local stakeholders into decision�making, which necessarily requires the consideration of socio-economic and institutional concerns along with the ecological concerns that provided the primary impetus for these conventions. In this light, successful conservation is less about biophysical aspects and rather more about the management and adaptation of governance systems across societal scales. | 52 - 52 | Prot-Adapt-Mitig- | | INDG |
| Adapting to Change (2011) | This is coupled with the observation that the conservation of forested habitats is not exclusively confined to the preservation of large and relatively undisturbed tracts of primary forest, but now also needs to include the often heterogeneous landscape matrices. While some tropical landscapes have been converted to large-scale intensive crop production or pasture, many others are comprised of diverse agricultural land uses, as well as natural habitat features such as rivers and streams, wetlands, natural grasslands, and forest remnants. The persistence of non�protected natural elements in these human dominated landscapes is invariably the result of long-standing local management practices, which may be imbued with cultural associations as well as livelihood needs. Further, in many tropical locations the distinction between agricul�tural and natural lands is often not so clear; many agricul�tural land uses, including various forms of shifting cultiva�tion and agroforestry, retain native trees and associated biodiversity to a considerable extent. Similarly, there is broad acceptance that forested areas can support liveli�hoods as well as biodiversity, particularly through the provision of non-timber forest products and various ecosystem services. In other words, anthropogenic land�scape mosaics that support biodiversity, ecosystem services and livelihoods, and encompass a wide range of cultural as well as biological values, are also worthy of conservation attention. This is particularly the case now, as many of these landscape mosaics are increasingly threatened by agricultural intensification. | 52 - 52 | Prot-Adapt-Mitig- | INTANBILE | |
| Adapting to Change (2011) | Existing frameworks for participatory landscape management Recognizing these issues is, of course, not sufficient to meet the various demands of conservation and local liveli�hoods. Systems of management need to be developed and implemented to account for the complexities and uncertainties inherent in any holistic land management programme. The main objectives of such a programme is the environmental sustainability and comparative prof�itability of local livelihoods, coupled with the conservation of biodiversity and the continued provision of ecosystem services to local, regional and global communities. | 52 - 52 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | There are several precedents for such programmes. The Model Forest approach (Box 1) leads from the bottom up and promotes sustainable forest management through local governance based on participation by all stake�holders. By recognizing a plurality of resource needs and rights, and by jointly identifying the barriers and challenges to meeting stakeholder aspirations (i.e. jobs, NTFP, recre�ation, hunting, wood, biodiversity conservation), it seeks to create a shared local vision for development from which all stakeholders would benefit. Other approaches have their origins in international research institutions such as ICRAF's Rewarding Upland Poor for Environmental Services (RUPES) initiative, which seeks to build capacity among poor small�holder communities to access and benefit from payments for environmental service schemes (Box 2). | 52 - 52 | Prot-Adapt-Mitig- | | INDG |

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| Adapting to Change (2011) | These schemes all seek broadly similar objectives, but they also face a similar set of challenges. Principle among these is the degree to which they are able to empower local communities to manage their landscapes in order to 54 2 Adapting to Change – The State of Conservation of World Heritage Forests in 2011 Enhancing Community Management of World Heritage Forests Through Landscape Labelling by Jaboury Ghazoul Institute of Terrestrial Ecosystems, Department of Environmental Sciences, ETH Zurich, Switzerland<br>deliver the broad objectives to which these approaches subscribe. Biosphere reserves provide government spon�sored international visibility, but the approach is largely top-down in that activities in core areas are constrained by regulations determined by the reserve's authorities, albeit often in consultation with agriculture and forestry authori�ties, administrations for water management, as well as local governments. The functioning of biosphere reserves is also heavily dependent on financial support from central governments, but when financial and political support is reduced the extent of participatory efforts declines. | 52 - 53 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Biosphere reserve administrations might also be perceived by local communities to be too closely tied to nature protection objectives and therefore not a neutral arbiter. | 53 - 53 | Prot-Adapt-Mitig- | | INDG |
| Adapting to Change (2011) | The Model Forest and the Community-based Payments for Environmental Service schemes must include effective locally inclusive and broadly representative institutions that provide accountability of local representation for decision�making and conflict management. These organizations need to be sensitive to gender issues and represent the interests of the poorest members of society. Trust between individuals, communities, regional and national govern�ments, and external actors is a basic condition for the successful outcome of negotiated agreements. Such conditions might be difficult to establish in community led approaches on account of the power and influence invested in certain stakeholder groups, social or ethnic classes, or individuals. Further, the success of these schemes assumes an adequate financing framework. The Model Forest promotes rural entrepreneurship through capacity-building and skills development, but commercial outcomes might conflict with forest and natural resource conservation objectives. Community-based Payments for Environmental Service schemes suffer from relatively high transaction costs of engagement that might limit small�holder participation. | 53 - 53 | Prot-Adapt-Mitig- | INTANBILE | INDG |
| Adapting to Change (2011) | Landscape labelling Building on this foundation is the concept of Landscape Labelling, which proposes that managed rural landscapes that are recognized to be delivering ecosystem services (based on local and regional evaluation by appropriate institutions) should be acknowledged as such through the designation of an exclusive 'Landscape Label' applicable across the whole landscape. A Landscape Label would represent the delivery of various ecosystem services, and thus be the conduit through which payments for ecosystem services to appropriate community-based organizations are made. Such payments would incentivize the continued delivery of these services through commu�nity-based management of the landscape. The Landscape Label could additionally be used to identify a product as originating from an ecosystem service-providing region, as Adapting to changes 55 2 Box 2. Community-based Payments for Environmental Services Reward schemes based on payments for environ�mental services (PES) seek to incentivize conserva�tion. Such schemes are often inefficient on private smallholdings (typically less than 50 ha), and this many poor smallholders are excluded from accessing such benefits. ICRAF's Rewarding Upland Poor for Environmental Services (RUPES) programme and the similar Pro-poor Rewards for Environmental Services in Africa (PRESA) (ICRAF 2008) seek to promote community-based action to socially and politically empower communities to engage in PES schemes. | 53 - 53 | Prot-Adapt-Mitig- | INTANBILE | |
| Adapting to Change (2011) | Box 1. Model Forest In Model Forests all stakeholders within an agricul�tural and forested landscape mosaic collaborate to manage the landscape's natural resources. Their management approach is based on their shared cultural history, and recognition of the landscape's natural values as well as their current and future economic needs. The collaborative partnership across stakeholders seeks to define sustainability in the local context, and then develops governance structures and strategic plans, to implement a set of common goals that seek to integrate economic and non-economic priorities. Important features of Model Forests are the comprehensiveness of their approach, the landscape scale of their oper�ation, and their inclusiveness. Model Forests are driven by bottom-up processes in that local stake�holders collectively set their own priorities, relating to conservation of biodiversity, economic enter�prise, public education, and infrastructural develop�ment. As such, the system is flexible and allows for local adaptation. well as serve to symbolize the wide variety of ecosystem services provided by the landscape. The Landscape Label could also represent and indeed publicize the cultural and symbolic attributes of the landscape, as defined by local communities, thereby helping to define its heritage value and uniqueness for people beyond the landscape. This in turn would provide greater recognition to communities, and help to empower them in negotiations with outside agencies (including government or companies), while promoting landscape recognition that could serve to generate new livelihood opportunities through, for example, tourism. | 53 - 54 | Prot-Adapt-Mitig- | INTANBILE | INDG |

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| Adapting to Change (2011) | A Landscape Labelling approach therefore provides a mechanism by which payments for environmental services are delivered to the community on the basis of effective landscape management. Individual landowners and producers additionally benefit from higher market recogni�tion of their products through the use of the Landscape Label as a certificate of good land and environmental management. Thus a Landscape Label potentially permits producer communities to improve market recognition, secure premium payments, gain access to niche markets, and attain market benefits for minor products by associa�tion through the label with more commercially important products. The derived benefits can, in turn, secure an incentive for managing the landscape in such a way as to continue to meet the ecosystem service criteria required for certification. Landscape Labelling potentially has other benefits such as reducing transaction costs, improving inclusivity and equity, cheaper conditionality determina�tion, allowing more flexibility in response to changing market environments, and providing social pressure to limit freeloading. | 54 - 54 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Landscape Labelling affords flexibility in management at the landscape scale. Thus one limitation of Payment for Environmental Services (PES) schemes is that landowners are contractually bound to restrict their land use activities, and are therefore limited in the extent to which they can respond to changing commodity markets. Assessing ecosystem service provision at the aggregated scale of the landscape, as proposed by Landscape Labelling, allows greater flexibility with regard to land use decisions. | 54 - 54 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | This raises the potential for landscape wide offset markets, permitting landowners to offset certain environmentally damaging activities while retaining the benefits of Landscape Labelling. Such flexibility is likely to make Landscape Labelling more attractive to wide participation, as there is recognition that high opportunity costs can be accommodated through reforestation or improved forest protection elsewhere within the landscape where opportu�nity costs are less. | 54 - 54 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Applying Landscape Labelling concepts to World Heritage forests World Heritage forest designation is applied to regions where forest ecosystems contribute to the site’s outstanding universal value. The broad objectives of World Heritage forest management must respond to threats (including invasive species, pollution of waterways, and forest conversion to agriculture) but in the context of human development ambitions. This in turn requires that different land uses, values, and management approaches be defined in consultation with local stakeholders. | 54 - 54 | Prot-Adapt-Mitig- | | INDG |
| Adapting to Change (2011) | Landscape Labelling can provide a mechanism by which local stakeholders can be more effectively integrated in World Heritage forest management. The World Heritage forest can provide the logical framework for a sustainable landscape management. For example, the overriding prin�ciple for the landscape might be ‘management to contribute to the long term conservation of the World Heritage forest, by maintaining its ecological connectivity with the broader landscape context’. Local landowners, NGOs, and community institutions that work towards this goal would be credited with the use of an exclusive ‘World Heritage Conservation Landscape’ label or certifi�cate, which could be exploited for commercial purposes such as product labelling or attracting payments for ecosystem services. | 54 - 54 | Prot-Adapt-Mitig- | | INDG |
| Adapting to Change (2011) | Landscape Labelling approaches rely on strong and repre�sentative community institutions responsible for coordi�nating activities across the landscape as well as the equi�table distribution of benefits through investments in community programmes and infrastructure. Often this is likely to require the strengthening of existing local stake�holder networks, and perhaps the establishment of new ones. The Model Forest approach thus provides an existing system to emulate. The adoption of a RUPES approach to the dissemination of ecosystem service payments with financial benefits invested through community based organizations for infrastructure development and social 56 2 Adapting to Change – The State of Conservation of World Heritage Forests in 2011<br>projects would ensure the broad and equitable distribution of benefits. Thus inclusivity and equitable distribution of benefits to all community members is an important element of Landscape Labelling. By allocating payments from ecosystem service buyers to community-based organiza�tions, and investing in social and community projects, the Landscape Labelling approach provides the potential to secure benefits to all community members including the landless poor. While these benefits are indirect, they may be important in providing improved access to markets, better education and healthcare, micro-insurance, and so on. | 54 - 55 | Prot-Adapt-Mitig- | | INDG |

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| Adapting to Change (2011) | People living within the broader World Heritage forest landscapes might additionally benefit through the use of a World Heritage Conservation Landscape label by which their products could be differentiated from others in the market place, thereby securing greater market access or possibly a price premium. This might be best applied to products with a large international market, such as coffee and cocoa, but could conceivably be applied more gener�ally. Indeed, the Landscape Label need not be restricted to a particular product, as is the case with most certification or labelling initiatives, but could be associated with a land�scape. Hence, any product that is derived from that land�scape can use the label to indicate that it has been produced under a management system that continues to provide ecosystem services. This provides benefits in terms of market recognition – and potentially price premiums – to all farmers regardless of the type of goods produced. | 55 - 55 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | The management of the World Heritage forest landscape, through the collective action of the communities living within it, would need to recognize and respond to the criteria of the World Heritage forest designation if the benefits of PES funds and the World Heritage forest label are to be maintained. These benefits, provided they are sufficient to overcome the costs (including opportunity costs), would therefore provide an incentive for local communities to work closely and align themselves with the World Heritage objectives to ensure the sustainability of the landscape. The success of community-wide schemes is dependent on effective institutional structures that provide appropriate negotiation and communication pathways among the variety of community organizations. A diversity of community-based organizations and interests is typical of many rural landscapes; ensuring effective interaction among such organizations is one of the most serious chal�lenges to the implementation of landscape-level PES processes. The success of the Landscape Labelling approach rests on the effective functioning of such organizations, and cooperation among them. Payments to support a certi�fied landscape are expected to be made to appropriate community institutions responsible for making investment decisions. Conflicts among community-based organizations and corruption within them is perhaps the single most important threat to the successful implementation of Landscape Labelling. Nevertheless, there is considerable awareness and knowledge regarding empowerment of and collaboration among community-based organizations, and examples of collaborative networks to secure wider community benefits are known. These include the Model Forest system, which encompasses a network of stake�holders that share the common goal of sustainable land�scape and forest management with a view to preserving ecosystem services and local livelihoods. | 55 - 55 | Prot-Adapt-Mitig- | | INDG |
| Adapting to Change (2011) | Indeed, there is increasing acceptance that forested land�scapes, encompassing other forms of land use and habitat cover than just forests, should be the focus of manage�ment attention and conservation. This implicitly recognizes humans as part of those landscapes. This thinking has led to a more inclusive and bottom up approach to manage�ment and conservation that integrates local stakeholder value systems and decision-making. | 55 - 55 | Prot-Adapt-Mitig- | | INDG |
| Adapting to Change (2011) | The Landscape Labelling approach seeks to provide mech�anisms by which such a bottom-up approach is linked to an internationally recognized programme though which access to PES funding might be promoted and ultimately realized. Thus well conserved World Heritage forests can form the basis of a rigorous logical framework against which sustainable development at the landscape level can be constructed. A healthy landscape, contributing to the long-term conservation of a World Heritage forest by, for example, promoting land use systems that improve ecological connectivity and that secure its integrity, could be formally recognized as such. The contribution of local communities to this objective, through appropriate land management, could be evaluated and recognized by a label through which PES might be sought and secured. | 55 - 55 | Prot-Adapt-Mitig- | | INDG |
| Adapting to Change (2011) | Moreover, through the use of the World Heritage forest name and label, the Landscape Labelling approach offers a second independent mechanism of securing market benefits from products emerging from a World Heritage forest. In this way, local communities might be able to secure real benefits from World Heritage status, and therefore gain increased incentive for its effective management. The Landscape Labelling approach suggests a strong community identity and effective local networks and institutions. The Model Forest Trust Network provides an example on how such identity and coherence might be developed and sustained. | 55 - 55 | Prot-Adapt-Mitig- | | INDG |
| Adapting to Change (2011) | 3 Jiuzhaigou Valley Scenic and Historic Interest Area, China © Andy Leong 59<br>Introduction The Convention on Biological Diversity (CBD) is an inter�national treaty for the conservation and sustainable use of biodiversity, and the fair and equitable sharing of benefits arising out of the utilization of genetic resources. Over the years, the Conference of the Parties to the CBD devel�oped programmes of work on thematic areas, correspon�ding to the major biomes the world. It also initiated work on key cross-cutting issues that are of relevance to all thematic areas. | 56 - 57 | Prot-Adapt-Mitig- | | |

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| Adapting to Change (2011) | The CBD's programme of work on forest biodiversity (CBD decision VI/22), for example, promotes measures to enable the conservation and sustainable use of forest resources and the equitable sharing of benefits arising from their use. Similarly, the CBD's programme of work on protected areas (decision VII/28) promotes the establishment and maintenance of comprehensive, effectively managed, and ecologically representative national and regional systems of forest protected areas. | 57 - 57 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Other targets that are also relevant to forests, aim to eliminate negative incentives harmful to biodiversity, apply positive incentives for conservation and sustainable use (Target 3), and to restore and safeguard ecosystems that provide essential services and contribute to health, livelihoods and well-being, in particular for women, Global Governance – What is the relationship between World Heritage Forests and Global Governance processes? | 58 - 58 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | • Decision X/32 on sustainable use of biodiversity invites Parties and other governments to implement the recom�mendations for the sustainable use and conservation of bushmeat species, developed by the CBD Liaison Group on Bushmeat in 2009. The decision requests the Executive Secretary to develop through the Liaison Group, options for small-scale food and income alterna�tives to bushmeat hunting that are based on the sustain�able use of biodiversity. The decision also requests the Executive Secretary to compile information on how to improve the sustainable use of biodiversity in a land�scape perspective, including sectoral policies, interna�tional guidelines, and best practices for sustainable agri�culture and forestry. | 59 - 59 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Key forest related activities of the CBD Secretariat ITTO and CBD Initiative Based on a Memorandum of Understanding and with generous funding from the Government of Japan, the Secretariat of the International Tropical Timber Organiza�tion (ITTO) and the CBD started a joint initiative for the conservation and sustainable use of tropical forest bio�diversity. The initiative supports the implementation of the CBD programme of work on forest biodiversity in ITTO producer member countries through specific country proj�ects related to capacity building, technical support and guidance. It builds on the experiences of the 'Friends of the PoWPA' in support of the CBD programme of work on protected areas. | 61 - 61 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | The implementation of the initiative is led by ITTO in close consultation with the CBD Secretariat and the Government of Japan. The initiative prioritizes activities related to relevant goals identified in the CBD's Strategic Plan. The country projects of the initiative focus inter alia on the linkages between forest biodiversity and climate change, biodiversity conservation in production forests, and transboundary conservation of tropical forest resources. The focus on transboundary conservation, in particular, may present new opportunities for existing or future World Heritage sites in tropical forests. | 61 - 61 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Conclusion The decisions of the Conference of the Parties to the Convention on Biological Diversity (CBD), in particular the Strategic Plan for Biodiversity 2011–2020, are highly relevant for the future management and possible expan�sion of the network of protected forests globally, including World Heritage forests and the Man and Biosphere Programme. The International Decade for Biodiversity 2011-2020 will be a decisive period in setting the right policies through National Biodiversity Strategies and Action Plans and other relevant instruments for a sustainable future, and for achieving the vision of the Strategic Plan that states, "By 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and deliv�ering benefits essential for all people." 64 3 Adapting to Change – The State of Conservation of World Heritage Forests in 2011 3. For more information on the CBD LifeWeb Initiative, please refer to: http://www.cbd.int/lifeweb<br>On 2 February 2011 the Secretariat of the United Nations Forum on Forests launched the International Year of Forests, also known as Forests 2011, to celebrate the essential role that forests play in the lives of billions. The network of World Heritage forests provides a unique plat�form where the benefits of forests can be better harnessed to both improve the well-being of people and the health of forests around the world. | 61 - 62 | Prot-Adapt-Mitig- | | |

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| Adapting to Change (2011) | Despite this, the social and cultural values of forests are only rarely mentioned. Two main reasons could be put forward to account for this. First, local people have long been held as culprits of environmental degradation, and particularly of deforestation. For much of the nineteenth and twentieth centuries, Western conservationists saw humans as the antithesis of nature, and believed that the former could only harm the latter. In more recent decades, both decision-makers and experts further emphasized the allegedly destructive role of local communities in a bid to wrest away both management and knowledge of forests respectively from local hands. In particular, shifting cultiva�tion (also known as slash-and-burn) and extraction of wood and non-timber forest products by communities for subsistence purposes were highlighted as the primary causes of deforestation. This also had the advantage of turning the attention away from other causes that included industrial logging and large-scale agriculture. | 62 - 62 | Prot-Adapt-Mitig- | INTANBILE | INDG |
| Adapting to Change (2011) | While experts deconstructed the discourse denouncing communities as the primary culprits of deforestation1, decision-makers began to see the benefits that community participation could have in all forms of sustainable forest management, including conservation. Despite such advances, however, local communities continue to be largely marginalized and their rights to access the multiple values of forests frequently denied, for the simple reason that they do not have the capacity to influence decision�making processes. | 62 - 62 | Prot-Adapt-Mitig- | | INDG |
| Adapting to Change (2011) | To cite just one example in Central Africa, the growing taste of urban populations for bushmeat has encouraged members of rural communities to contribute to the alarming depletion of forest wildlife well beyond their subsistence needs. Likewise, in eastern Democratic Republic of the Congo, the participation of communities in the charcoal trade to provide fuel to the region's cities has become one of the greatest threats to a number of protected areas, including the World Heritage Okapi Wildlife Reserve. It is therefore essential to strike a balance between the different functions of forests so as to ensure that the use of forests, whether by local communities or large-scale industries, remains compatible with the preservation of ecosystem services, particularly in the world's most ecologically valuable forests such as those inscribed on the World Heritage List. | 63 - 63 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | 67 3 3. IUCN Category Ia: Strict Nature Reserves; Ib: Wilderness Areas; II: National Parks. Due to the great fragility of these natural ecosystems, the use of the environment by local communities is often extremely restricted or simply non-existent in these categories.<br>'Forests for People', the main theme of the 2011 International Year of Forests (IYF), highlights the ecolog�ical, economic and cultural importance of forests for human life as well as the central role of people in the conservation and sustainable management of the world's forests. By placing people at the heart of the current global debate on forests, IYF places emphasis on the power of human action not only as part of the problem, but also as part of the solution. | 64 - 65 | Prot-Adapt-Mitig- | INTANBILE | |
| Adapting to Change (2011) | During the past four decades, the biosphere reserve concept, which originated in the framework of the MAB Programme, evolved from a conservation focus to its current form of land and seascape units dedicated to sustainable development. The adoption in 1995 of the Seville Strategy and Statutory Framework of the World Network of Biosphere Reserves was a key milestone in this evolution as it reaffirmed biosphere reserves as internation�ally recognized sites with three interconnected goals: biodi�versity conservation; social, economic and cultural develop�ment of local communities; and learning on sustaining mutually beneficial relationships between conservation and development through research, monitoring, education and capacity-building. It also called for systematic adoption of a multi-stakeholder governance system, and the specific biosphere reserve zonation system comprised of a legally protected core area surrounded by buffer and transition zones, including resident communities. | 65 - 65 | Prot-Adapt-Mitig- | INTANBILE | INDG |
| Adapting to Change (2011) | In the exploration of the relationship between World Heritage forests and biosphere reserves, forest biosphere reserves can certainly bring useful experience, insights, tools and techniques in order to inter alia: • decrease ecological isolation through increased connec�tivity; • strengthen the contribution of local communities to forest conservation and sustainable management, linking forest conservation to climate change responses; and • improve generation, collection and sharing of relevant ecological and social knowledge, and best monitoring and management practices. | 65 - 65 | Prot-Adapt-Mitig- | INTANBILE | INDG |
| Adapting to Change (2011) | Giving incentives to local communities to plant trees, for example, payment through ecosystem services schemes, not only promotes ecological connectivity but also contributes towards climate change mitigation efforts by enhancing carbon storage and sequestration processes. | 67 - 67 | Prot-Adapt-Mitig- | | INDG |

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| Adapting to Change (2011) | ii) Bia Biosphere Reserve (Ghana) Another example to promote ecological connectivity has recently been initiated in Ghana where communities bordering the Bia Biosphere Reserve are encouraged to sustainably use and manage wildlife resources within a defined area through the creation of biological corridors, referred to as community resource management areas (Attuquayefio and Fobil, 2005). In the long term, the idea is to create similar community managed corridors from the core area to other protected areas in the region, and also to other areas in Côte d'Ivoire. | 67 - 67 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Similar and other types of community involvement in forest management and governance have been initiated in biosphere reserves worldwide. Experiences, ranging from the Luki Biosphere Reserve in the Democratic Republic of the Congo (DRC) to Clayoquot Sound Biosphere Reserve in Canada and Maya Biosphere Reserve in Guatemala, have shown that the success of community involvement depends on many factors. However, they all concur that community participation at all levels of the management process – from planning, intervention to monitoring – and the respect for their traditional rights and social and cultural values are key to the success of joint management schemes (Kotwal et al., 2008). In the long term, the combination of scientific, local and indige�nous knowledge and practices, and the adaptive nature of community driven approaches to forest management greatly benefits the sustainability of forest ecosystems, while boosting economic returns and contributing to sustainable development on local and regional scales (Persha et al, 2011). | 67 - 67 | Prot-Adapt-Mitig- | INTANBILE | INDG |
| Adapting to Change (2011) | iii) Forest Conservation and Climate Change With the intensified debates linking forest conservation to climate change resilience, forest biosphere reserves and World Heritage sites are expected to adopt strategies to address the challenges of climate change mitigation and adaptation, such as land use changes that integrate the conservation and sustainable use of forest resources with positive social and forest based livelihood outcomes. | 67 - 67 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Interesting opportunities in terms of new incentives to prevent deforestation and for sustainable forest manage�ment are offered by the REDD (Reducing Emissions from Deforestation and Forest Degradation) and REDD-plus financial mechanisms. In particular, REDD-plus not only includes traditional approaches to reduced deforestation and degradation, but also covers elements of conservation, sustainable forest management and enhancement of carbon sinks. Hence, the role of forest World Heritage sites and biosphere reserves, including sites with both designa�tions, as well as those with forested landscape linkages in their surroundings, assume special significance. Forest World Heritage sites and biosphere reserves could specifi�cally explore how the improved protection and sustainable management of forested landscapes within and around them could contribute towards improving the conservation of these sites while yielding benefits for a broad range of stakeholders, particularly the dependant local communi�ties. Although much remains to be defined in terms of eventual mechanisms for the implementation of REDD, especially the flow of benefits to communities and people directly involved in land use decision-making and forest related livelihoods, some biosphere reserve authorities are taking initiatives in line with developing climate change mitigation and adaptation options and income generation options for the sites and local communities. | 67 - 67 | Prot-Adapt-Mitig- | | INDG |
| Adapting to Change (2011) | Another component of this pilot project involves giving financial incentives to local communities to ensure the protection and natural regeneration of the savanna ecosystem in the area. The overall goal is to implement a sustainable development model around the Luki BR that will be integrated into the national REDD-plus strategy in order to decrease the rate of deforestation, as well as ensure the production of ecosystem goods and services to the local communities. | 68 - 68 | Prot-Adapt-Mitig- | | INDG |
| Adapting to Change (2011) | Together, World Heritage sites and biosphere reserves cover approximately 300 million hectares of forested land�scapes. As sites that are internationally recognized for their outstanding universal value and their contribution to multi-scale sustainability, they are expected to provide models for the protection of the world's forests while enhancing the vital ecosystem services they provide for human well-being. Sharing of knowledge, experiences and good practices within, between and outside these sites, combined with the search for and implementation of effective and innovative ways to enhance the benefits of separate and joint World Heritage–Biosphere Reserve designations in terms of biodiversity conservation and sustainable use, responses to climate change and commu�nities' well-being, should be seen as a priority in UNESCO's contribution to sustainable development from local to global levels. These endeavors should be guided by the recognition that people are an integral part of the bios�phere, and that the economic, social and cultural values they associate with biodiversity, including its forest compo�nents, will be critical in triggering the behavioral changes that are needed to allow for a more sustainable society for the benefit of present and future generations. | 68 - 68 | Prot-Adapt-Mitig- | INTANBILE | |

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|---|---|---|---|---|---|
| Adapting to Change (2011) | a National Park. The Polish part of the site was inscribed on the World Heritage List in 1979 while the Belarusian part was added in 1992. Due to huge differences in political systems, as well as nature conservation policies in both countries, each part is managed separately, however a joint management frame�work has been elaborated and accepted by the manage�ment authorities in both countries. Since the Belarusian part was added, there has been a major disparity in size and management between the two areas. The Polish part of the site consists almost exclusively of forest habitats, which have been subjected to a strict protection regime for over eight decades. This area is surrounded by a large forest complex, which in terms of management forms a complicated mosaic of patches of different protection regimes as well as productive forests. The World Heritage site (5,0 ha) also borders the forest lands added to the national park in 1996 (5,155 ha). Out of 53,000 ha managed by the State Forest Administration, 3,600 ha form Bial/ owiez. | 70 - 70 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | a National Park's buffer zone. There are no separate regulations on the forestry practices within the buffer zone but hunting is forbidden there. Another 12,012 ha enjoy nature reserves status. Even though the reserves do not fall under a strict protection regime, timber exploitation is banned. Tree cutting is permitted only for safety reasons and the wood has to remain in the ecosystem. Hunting is also forbidden in the nature reserves. For each nature reserve, management plans should be prepared where detailed information on activi- 74 4 Adapting to Change – The State of Conservation of World Heritage Forests in 2011 Belovezhskaya Pushcha/Bial/ owiez. | 70 - 70 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | a Forest 000 56 56<br>ties permitted must be elaborated. Activities permitted are planned in accordance to the main objective of the reserve. Reserves established for the protection of butterfly fauna or grassland habitats are managed in a different manner to those established for the old growth forests. | 70 - 71 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | a Forest, the absence of timber exploitation throughout the centuries has ensured conti�nuity in terms of fluctuations of tree stand development processes. Individual trees are able to live until their natural death, reaching exceptional dimensions, unparalleled in other forest complexes of Europe. Within the strictly protected area, one can find exceptionally high amounts of dead trees, where strict conservation measures are in place. | 71 - 71 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | a Forest divided by the border fence into two herds. In the Polish part of the forest there are over 470 individuals and it is estimated that the existing mosaic of forest and non-forest habitats, as well as the proper management of the bison, can support such a population. It is clear that the long-term genetic viability of many Bial/ owiez. | 71 - 71 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Areas described by experts as ecological corridors are not currently protected as such in Poland. They may fall under different forms of protection if they form part of a protected area, such as a national park, nature reserve or landscape park. It is highly recommended though that ecological corridors, including watercourses, should be protected by national law. In 2005, the Polish Ecological Corridors Network was developed, financed by the Case Studies – On Connectivity 75 4 The Bial/ owiez. | 71 - 71 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | a National Park was doubled when the area of 5,155 ha of managed forests was included in the park. The newly included forests are situated along the western and northern borders of the World Heritage site. The managers of these two areas, now joined under one national park, had to take into account that it was subjected to regular forest management practices, and the change of approach should be evolutionary. During the first years, the sanitary cuttings were continued and the amount of exploitation was based on the extent of bark beetle gradation. Starting from the year 2000, statis�tics show a reduction in the quantity of timber exploited due to a change of management approach. Today, the bark beetle is regarded as a natural element shaping ecosystems of the national park, therefore sanitary cuttings have dropped down to almost zero (Figure 2). | 73 - 73 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | The area of strict protection in the national park now measures 6,061 ha. The remaining forest ecosystems (4,456 ha) of the park are partially protected, but the long-term management plan does not include timber exploitation in the area. As the connection of local communities, who have existed here for centuries, and the forest should be maintained, part of the area cannot be closed to people therefore it cannot fall under a strict protection regime. Visiting without a guide is permitted, as well as riding bicycles along marked trails, and picking berries and mushrooms. Meadows and grasslands, espe�cially those situated along the river valleys, are cut in order to maintain enough food for grazers, including the bison. As the entire Bial/ owiez. | 73 - 73 | Prot-Adapt-Mitig- | | |

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| Adapting to Change (2011) | a Forest is recognized under the Natura 2000 network, management of the area has to take into consideration the requirements of the European Habitat and Bird Directives. Hence, open habitats, shaped in the past by natural elements as well as human activities, should be maintained in order to support populations of species currently listed in the Annexes to European Union Directives, such as the lesser�spotted eagle and the corncrake. | 73 - 73 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | a Forest is surrounded by a mosaic of natural landscapes, such as forests, peat bogs, meadows, pastures and arable land. There is no industry and the most urbanized area is the town of Hajnowka, inhabited by some 20,000 people. Management of the Case Studies – On Connectivity 77 4 Timber exploitation (m3 ) Year 5000 4500 4000 3500 3000 2500 2000 1500 500 0 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 Figure 2. Timber exploitation in the Hwoz. | 73 - 73 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | na Protected Area Analyzing the amount of timber exploitation from the area added to the national park, one can observe the evolution in the management approach.<br>forest habitats administered by the State Forests varies depending on the status of particular fragments. Even though the nature reserves (12,012 ha) do not fall under a strict protection regime, timber exploitation and hunting is banned there. In the State Forests' part of the forest there are also numerous regulations, different to those in a typical production forest. Tree stands over 100 years old cannot be exploited, heavy machinery cannot be used, and an inventory of species has to be done before any activities can be undertaken. | 73 - 74 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Data show that 60 years ago spruce constituted over 25 per cent of the surface in the forest, in the 90s it was 16.6 per cent, while today it varies between 5–8 per cent. The surface percentage of oak remains at the same level at 19 per cent. Other species, such as lime and hornbeam, increase the surface percentage to 30 per cent. The fall in percentage of spruce is directly caused by more intensive and frequent gradations of bark beetle. However, it is necessary to bear in mind that bark beetle infestations are a secondary factor as bark beetles infest trees already weakened by other factors, such as long dry periods, strong winds that break or fell trees, high temperatures or a lowering of the groundwater table. These changes are recognized in the long-term management plan for the national park and regarded as existing and potential threats for existing ecosystems. Nevertheless, it is agreed that the main actions will involve monitoring of the processes and implementing practical measures, as much as possible, which allow the ecosystem to adapt to changes. Throughout its history, the forest has witnessed different climatic periods, but its very existence was never threatened. The main mission of the Bial/ owiez. | 74 - 74 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | a National Park and the State Forest Administration was, 'Protection of Emys orbicularis (European pond turtle) and amphibians in the north European lowlands'. One of the goals of that project was creating breeding and feeding habitats for amphibians as well as their protection during spring migration between forest and grassland habitats. | 75 - 75 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Within the area of the park as well as in the surrounding private lands there were new ponds created, supporting not only breeding populations of amphibians but also serving as water reservoirs for other animals and facili�tating migration of numerous species. Enhancing connec�tivity of ecosystems is also the aim of Protection of lesser�spotted eagle in Natura 2000 sites. The species nests in forest but feeds on grasslands and cut meadows – large scale meadow reclamation in the area of the Bial/ owiez. | 75 - 75 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | a Forest had been protected in 1921. We would definitely have had the unique chance to observe natural processes on a much larger scale than today. It is also certain that some species currently living in the forest would have become extinct. The concept of nature protec�tion has changed over the twentieth century. Forest management practices and the perception of forest func�tions has also changed, though slowly. Knowledge on the functioning of ecosystems and some species' requirements has been much enhanced today. We should therefore use the experience gained as best we can so as to create a new formula for the Bial/ owiez. | 75 - 75 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | It has been already observed that the non-productive functions of forests have a growing number of supporters, and there is even more support for protection. As a result, the protection regime of the Bial/ owiez. | 75 - 75 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | a Forest often experiences conflict and heated debate over the form of management and protection that should be implemented. Moreover, the issue receives a great deal of international attention and various pressure due to its World Heritage status and to its European Diploma of Protected Areas designation. The management policy of the State Forest Administration was severely criti�cized over the past decades. Nevertheless, conflicts – if kept within healthy limits – can be constructive and this seems to have been the case in the Bial/ owiez. | 75 - 75 | Prot-Adapt-Mitig- | | |

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| Adapting to Change (2011) | In an effort to conserve these natural areas, countries in the region have made a considerable effort to remedy the situation and have established 526 protected areas inter�linked through a network of connected conservation corridors, known as the Mesoamerican Biological Corridor (MBC) – see figure 1. Since the early 1990s this initiative, originally known as Paseo Pantera (The Path of the Panther), received strong international support up until 2006. Today, many national efforts continue in addition to the second phase of the MBC Project announced by the Central American Commission of Environment and Development (CCAD) during the Convention on Biological Diversity (CBD) COP10 in Nagoya in 2010. | 76 - 76 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Sustainable development is achieved in biosphere reserves using an established system of governance that is partici�patory in its structure: land use planning is determined by a gradient of different uses, from core zones that are dedi�cated mainly to conservation, to buffer zones that are sustainably managed, and transition zones where human activity is greater and where benefits are shared with the local population. Local participation in conservation, devel�opment and research, and learning initiatives will allow for true empowerment of local communities. The biosphere reserve concept is well established and has gained impor�tance with several new nominations in recent years, but has to be strengthened and better enforced. Meanwhile, World Heritage sites offer a unique opportunity to show�case best management practices and increased manage�ment effectiveness and should serve as demonstration sites on how to achieve conservation within the national protected area systems. | 76 - 76 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Though these sites are faced with conservation challenges of their own, in relation to land use changes in the rest of the landscape in which they are located, they are rela�tively well conserved. As such, they are well positioned to play a key role as conservation nodes at the regional level. | 76 - 76 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Conclusion Conserving the biodiversity and forests in the region requires the strengthening of institutions, the develop�ment of well targeted and enabling land use policies, the promotion of inter-sector cooperation, and the empow�ering of local communities, mainly through education and by increasing their communication and access to informa�tion. While mitigation strategies are globally driven and the carbon markets are being handled by a diverse set of organizations, adaptation strategies will have to be developed locally. This implies that research and informa�tion networks have to be established, while the meteo�rological network must be strengthened. Local people and professionals must be trained to use information for deci�sion-making. Local knowledge must be incorporated into knowledge systems. | 80 - 80 | Prot-Adapt-Mitig- | | INDG |
| Adapting to Change (2011) | The use of protected areas as natural solutions to both mitigation and adaptation will be vital (Dudley et al., 2010). Results from surveys conducted in the 1990s indicate that 80 per cent of the forest cover remained in protected areas, while only 31 per cent remained outside of these areas (Sader et al., 2001). Current efforts by the CCAD (Comision Centroamericana de Ambiente y 84 4 Adapting to Change – The State of Conservation of World Heritage Forests in 2011 Source: FAO (2011) State of the World's Forests 2011. | 80 - 80 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Of the mechanisms and designations mentioned above, only World Heritage sites enjoy systematic monitoring on the state of conservation on behalf of the global commu�nity through the World Heritage Committee. The Committee, in this capacity, has a unique role to play in dialoguing with national governments to encourage the adoption of necessary measures designed to guarantee the long-term conservation of World Heritage sites. In many cases, the World Heritage Committee has requested that governments take action in matters well outside the boundaries of the World Heritage site in order to better ensure the site's conservation. In light of such precedents, it is not unreasonable to consider the role the World Heritage Committee can play in encour�aging governments to pay more attention to connectivity issues, and to implement measures such as those mentioned above, not only as good management prac�tices, but also as a strategy to adapt to climate change. | 81 - 81 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Case Studies – On Connectivity 85 4<br>Introduction The principle of World Heritage is based on the recogni�tion of outstanding universal value granted to a cultural or natural site with an emphasis on the conservation and manifestations of this value. Through the years, the partic�ipation of local stakeholders in matters of conservation has been recognized as essential in achieving success. In this regard, the concept of the biosphere reserve leads the way in seeing beyond the nature reserve as hunting grounds of fauna once used by colonialists through the involvement of local populations. However, despite the institutional attempts to reach a balance between conservation and development, forest related conflicts still persist, particu�larly between the managers of protected areas and resi�dent populations. Several attempts to settle these conflicts have been put in place, but tensions remain and have yet to be resolved. | 81 - 82 | Prot-Adapt-Mitig- | | INDG |

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| Adapting to Change (2011) | After a decade of harmonizing forestry policies in the countries adjoining the Congo Basin, the decentralization of natural resources management remains an important issue for in situ biodiversity conservation strategies world�wide. This importance demonstrates the central role played by local stakeholders in biodiversity governance strategies, while taking into consideration their interests and diversity. Environmental governance, conceived as a framework for multi-stakeholder dialogue and resource management, distinguishes itself from the ideology of social exclusion. Consequently, Model Forests 3 act within the processes of conflict resolution so as to facilitate community dialogue. As well as linking poverty and devel�opment issues, Model Forests also offer a framework of innovation, the promotion of local entrepreneurship, and experimentation on alternative projects of natural resource management. Model Forests also work towards a process that leads to 'standing on their own two feet' by inno�vating in terms of environmental governance and the improvement of living conditions for local populations. | 82 - 82 | Prot-Adapt-Mitig- | | INDG |
| Adapting to Change (2011) | On April 28, 2008, Decision No. 0330D/MINFOF/SG/DFAP was taken regarding the management structure of the Dja Faunal Reserve. The text defined its organizational structure consisting of a new managerial framework comprising a Management Committee (MC), a Consultative Committee (CC), a Scientific and Technical Committee (STC), and a Conservation Service (CS), which is the operational arm consisting of forestry stations and communication satellites within the DFR. Given the diverse stakeholders involved, as well as the application of the management's measures, the DFR's vision and objectives evolved such that today, the protected area is considered as a natural and social environment that favours the emergence of frameworks of cooperation and dialogue between the various stakeholder groups. | 82 - 82 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | 86 4 Adapting to Change – The State of Conservation of World Heritage Forests in 2011 Multi-actor Partnership and Sustainability Management of Biodiversity: The Case of the World Heritage Site of the Dja Faunal Reserve (DFR) by Gustave Ossie Ompene, Patrice André PA'AH1, Théophile Bouki 2, Jean-Claude Stone Njomkap 2, Julie Gagoe Tchoko 2 and Mariteuw Chimère Diaw2 1. Respectively, Focal Point and Executive Secretary of the Model Forest of Dja and Mpomo (FOMOD) 2. Secretariat of the African Model Forests Network (AMFN) 3. The concept of Model Forest was conceived in Canada in the 1990s and was adopted by the government of Cameroon in 2005, and is described as a 'partnership aimed at accelerating the application of sustainable development by systematically taking into consideration the interests of every stakeholder...'<br>This paper attempts to demonstrate the different positions held in terms of sustainable management by the DFR, and how they integrate dialogue in the FOMOD, and how, in return, local, private, public and community stakeholders could be encouraged to contribute towards the ecological integrity of the DFR. These conditions are essential to the dynamic of local development. | 82 - 83 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | History of the occupation of DFR by local populations and the new management approach to fauna For several centuries the DFR has been occupied by the Ndjemé, Nzimé, Badjoué, Baka, Bulu, and Fang ethnic groups (Tchikangwa, 1996). These populations lived in the forest environment as hunter-gatherers, and used their surroundings for agriculture and cultural rites. Visible traces of their occupation can be seen in the abandoned cocoa and coffee plantations in ancient forests, by the dikes crossing certain swamps, the sanctuaries, and inci�sion marks left on trees from tapping rubber (Oyono, Diaw and Efoua, 2000). These subsistence practices have never posed a threat to biodiversity and no species has ever been at the brink of extinction as a result, despite the fact that the diet of these populations was essentially based on meat and fish (Madzou, 2008). Consequently, several studies have shown that native populations have ethno�scientific knowledge of plants and therefore were able to benefit from their dietary, therapeutic or mechanical virtues, as well as exploit animal resources, with a principal focus on big mammals (Dounias, 1999; Oyono, 2002). | 83 - 83 | Prot-Adapt-Mitig- | INTANBILE | INDG |
| Adapting to Change (2011) | Not only does this contribute to the degradation of the environment but it also leads to conflicts over uses. These factors have contributed in creating groups of stake�holders with divergent interests around the reserve. Thus management decisions in the DFR remain potentially contentious with regard to approaches that seek to valorize natural resources as well as financial returns on activities led by certain investors. The confrontation of these different interests has immediate consequences on the area such as the escalation of illegal activities, namely poaching and illegal exploitation of the forest. | 83 - 83 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Faced with the real threats to the sustainable management of the DFR, several actions were carried out by the Ministry of Forest and Fauna (MINFOF) so as to reinforce its control, but also to spurr anti-poaching campaigns with the help of partnerships established between the different Model Forest stakeholders. A consultative framework set up at the local level soon became a platform for dialogue between the many partners. Examples include: • Partnerships forged between forestry and mine devel�opers and the local population, represented by their local forestry committees, through local consultative committees. | 83 - 83 | Prot-Adapt-Mitig- | | INDG |

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| Adapting to Change (2011) | Protection and management of natural and cultural heritage This coincides with the mission of the World Heritage site with respect to Dja's exceptional heritage and its natural areas and biodiversity. In common with the DFR, the FOMOD, is watchful over the long-term protection and management of the environment, particularly the more fragile and vulnerable environments such as wetlands, agricultural areas in transition, forest lands, flood areas, mountain ranges with little fragmentation, flooded wood�lands, forests in ravines, and biodiversity corridors. The DFR must also guarantee the dynamic conservation of landscapes and sites identified as remarkable and/or fragile. In this context, the Model Forest partnership has a serious responsibility to both protect and valorize the area's natural heritage. | 84 - 84 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Experimentation The FOMOD mobilizes stakeholders, techniques, and legal and statutory capacities to experiment and develop new solutions that are capable of contributing towards the different objectives defined by the DFR. Moreover, it contributes towards identifying research topics and towards facilitating the implementation of research or R&D programmes that could be transferred to other Model Forests within the framework of knowledge management; a system of sharing knowledge. This repre�sents a major sub-regional point of reference for issues related to the application of sustainable development in protected areas. | 84 - 84 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Building linkages to support environmental governance: the necessity of an institutional consultative framework In its strategy of promotion and support of decentraliza�tion for good forestry governance, the Dja and Mpomo Model Forest aims to reinforce its consultative framework so that it is acknowledged in the field of multi-stakeholder management. This would require cooperation from all stakeholders having activities in and around the DFR. | 84 - 84 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Accords between operational partners would encourage the emergence of local governance that allows for the sustainable management and integrated development of the physical and social environment, as well as the applica�tion of 'good practices' in forest planning without chal�lenging the rights and obligations of partners. An analysis of ongoing projects reveals that a real dynamic of change could be developed based on the multiple exchanges 88 4 Adapting to Change – The State of Conservation of World Heritage Forests in 2011<br>between institutional stakeholders. Currently, this involves providing feedback to those initiatives developed by the different partners so as to enable each actor to respond to a number of key issues raised through close collaboration, shared learning, and innovation. | 84 - 85 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Furthermore, conflicts are an integral part of the social game whose objectives are constantly changing. The ques�tion is whether the 'Model Forest partnership' is sufficient to reassure stakeholders, individuals or institutions that have difficulties in recognizing the value of working together. Unfortunately, this is fairly common and the reason why they should be consistently reassured of the good working and organizational conditions, which facili�tates open democracy, including freedom of expression, internal discussion, and conviviality. The institutionalization of co-management and the capacity-building of FOMOD's groups of stakeholders are open opportunities to reinforce consultation and partnerships that seek social compro�mise. In this vein, FOMOD plans to mobilize resources to create an information centre on social forestry with head�quarters located in Lomié. This centre will help create a database that benefits and documents local skills and scientific knowledge on all the local resources, including biodiversity management inside and outside the DFR. Such an initiative would have environmental benefits and ease tensions and prevent conflicts. Thus, projects leaders working for example on medicinal plants and traditional pharmaceutics, will better perceive the benefits of dialogue and cooperation with others. | 85 - 85 | Prot-Adapt-Mitig- | INTANBILE | INDG |
| Adapting to Change (2011) | In forest co-management, the creation of linkages between stakeholders minimizes the time and energy spent on conflicts and therefore attention can easily be directed towards establishing participative actions on envi�ronmental management. The FOMOD has identified ways to reconcile biodiversity conservation and the multi-uses of the environment for the purpose of sustainable develop�ment. Within this framework, farmers whose practices are based on constructive collaborative action will be better aware of the relationship between the needs for local development and environmental issues. The challenge for FOMOD is to reconcile environmental conservation with promoting local development within the context of ever�changing rural societies. | 85 - 85 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Relying on an evolving legal framework, particularly decentralized taxation, the partnership seeks to develop local mechanisms of distribution and benefit-sharing from forest management for the population. It intends to encourage harmonization and awareness raising among all the stakeholders concerned with biodiversity conserva�tion issues within the World Heritage site and its borders. | 85 - 85 | Prot-Adapt-Mitig- | | |

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| Adapting to Change (2011) | The FOMOD actively works towards synergy in its actions in order to provide every stakeholder with an opportunity to find solutions to their own problems, and to achieve its objectives while reconciling environmental conservation and the development of economic activities. Benefits to the environment will only be effective if there are mutual advantages, for example, a FOMOD project is producing high quality pens using wood residues from community forests. Although this is still in its experimental phase, particularly its transformation into an equitable and Case Studies – On Connectivity 89 4<br>sustainable business, this project demonstrates the feasi�bility of a FOMOD economic and environmental project in the eyes of the stakeholders. Reaching a social compro�mise in terms of mutual benefits requires the creation of a framework of broad consultation and dialogue among all stakeholders and at all levels – from indigenous people and farmer communities through to forest administrations, forestry and mine developers, rural elites, and so on. | 85 - 86 | Prot-Adapt-Mitig- | | INDG |
| Adapting to Change (2011) | Conclusion An adage known to all inhabitants of the Dja river says, 'In a group of fishermen aboard the same boat, each member is personally responsible for the safety of all because, in case of shipwreck, even the best swimmer will get wet before reaching the shore.' This adage suggests that the development of partnerships for biodiversity conservation in the DFR calls on the participation of all stakeholders. | 86 - 86 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Since the implementation of the Cameroon Model Forest process, the DFR management has evolved in line with the spirit of the great names of contemporary environ�mental governance, from the Brundtland report (1987) and the Rio conference (1989), to the Cameroon and Congo Basin forestry decentralizations established since the mid 1990s. Within this political and conceptual space, Model Forests have positioned themselves as a forum for the development and application of sustainable develop�ment at various local, regional and global scales. | 86 - 86 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Cameroon joined this movement in the mid 2000s and has made real progress to date. However, as highlighted by several authors, for example, Dounias (1999), recon�ciling the needs of conservation and the necessity for productive human development remains an extremely complex task. Achieving success in this process remains a pivotal issue for FOMOD and the DFR, whose manage�ment aspires to environmental conservation and the equi�table distribution of benefits. | 86 - 86 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Within this context, the largest tropical dry forest of South America, the Chiquitano Dry Forest, originally distributed over Bolivia, Brazil and Paraguay (Figure 1(a)), and declared a Model Forest by the International Model Forests Network, maintains good ecological integrity and func�tionality levels. This is due in large part to slow-moving socioeconomic and demographic development in eastern Bolivia – its principal geographic distribution area (Dinerstein et al., 1995; Ibisch et al., 2003) – but also to an important network of protected areas and existing forest concessions across its entirety (Vides-Almonacid, Reichle and Padilla, 2007). Today there are more than 15 million hectares of almost continuous forest coverage, consti�tuting an opportunity to design and implement integral ecosystem management strategies that, through the sustainable use of wood resources, non-wood resources and key environmental services, such as water and carbon stock maintenance, allows for the establishment of a base for its management and conservation. | 87 - 87 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | The Chiquitano Dry Forest links more than 11.8 million hectares of parks and reserves of different categories and jurisdictions, some of great value for humanity. Among these, the Noel Kempff Mercado National Park (with 1.5 million ha), declared a natural World Heritage site, as well as Ramsar sites such as the Bolivian Pantanal and Concepcion, Kaa-Iya del Gran Chaco National Park (one of the largest parks in South America with 3.3 million ha), Otuquis National Park, San Matías ANMI (Natural Area of Integrated Management), Tucavaca Valley Reserve, Ríos Blanco y Negro Wildlife Reserve, among various others of national, regional and local importance (Figure 1(a)). | 87 - 87 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Case Studies – On Connectivity 91 4 Ecological Integrity and Sustainable Development in the Chiquitano Dry Forest, Bolivia by Roberto Vides-Almonacid and Hermes Justiniano Chiquitano Forest Conservation Foundation (Fundación para la Conservación del Bosque Chiquitano)<br>This is in addition to the more than twenty-two forest concessions, amounting to almost 2.2 million ha, of which eight (868,000 ha) are certified under the Forest Stewardship Council (FSC), as well as twelve community lands (more than 6 million ha) of the Baure, Chiquitana, Ayoreode and Guarani communities, and a significant number of small private reserves and other local forest concessions (Figure 1(a)). This extensive and heteroge�neous mosaic of land use rights, superimposed in many cases, confers a complex panorama in terms of gover�nance. But at the same time it also provides an opportu�nity-filled setting for counteracting deforestation trends, encouraging connectivity between large areas of protected forests, and promoting the conservation and sustainable use of biodiversity. | 87 - 88 | Prot-Adapt-Mitig- | | |

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|---|---|---|---|---|---|
| Adapting to Change (2011) | Land management strategies In view of this assortment of threats and opportunities, a series of land and natural resource management strategies can be added to the pile, which – when adequately formu�lated and implemented – could contribute to maintaining the ecological integrity of the Chiquitano Dry Forest in the long term. Land-use planning has different geographic and jurisdiction scales on the one hand, but on the other, the policies applied to the use of natural resources and access rights generate a basis of technical, socioeconomic and political criteria for the appropriate use of land, and the planned occupation of the area. | 88 - 88 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | In the land use planning process, four instruments, corre�sponding to the different scales, must be represented: the Departmental Land Use Plans (in this case, of the depart�ment of Santa Cruz, Bolivia, where the majority of the Chiquitano Dry Forest is located), the Municipal Land Use Plans (PMOT – protected by the New Political Constitution of the Bolivian State), the Indigenous Land Management Plans (applied to native and peasant community lands), and the Land Use Plans (applied to private farms). Each one of these instruments constitutes management oppor�tunities that could promote connectivity on multiple scales, as well as the protection of sites – key for the func�tioning of ecosystem services such as water, the conserva�tion of biodiversity (establishing protected areas), and for the identification of areas of forest susceptible to defor�estation or degradation on which mechanisms like REDD+ could be applied. The PMOT design for the Chiquitana 92 4 Adapting to Change – The State of Conservation of World Heritage Forests in 2011 Figure 1. Chiquitano Dry Forest Ecoregion Figure 1(a) shows the different usage rights in the Chiquitano Dry Forest Ecoregion; Figure 1(b) the distribution of three non-wood forest products and Figure 1(c) indications of the design stage of municipal land-use plans in several municipalities of the Chiquitano region. | 88 - 88 | Prot-Adapt-Mitig- | | INDG |
| Adapting to Change (2011) | For its part, the use of forest resources, under regulations currently in force in Bolivia, allows for large areas of the Chiquitano forest to be kept in good health, especially if they are found to be under voluntary certification mecha�nisms, creating a source of connectivity and ecological integrity opportunities. The use – still incipient – of valu�able non-wood forest resources, such as the Chiquitana almond (Dipteryx alata), cusi palm (Attalea speciosa) or copaibo oil (Coppaifera spp.), also creates a promising option for establishing extensive protection areas for its long term management. Recently, one of the municipali�ties of the Chiquitano Dry Forest created a new protected area (347,000 ha), stemming from the interest in main�taining and managing the natural forest under a non�wood products exploitation scheme, in this case, for the extraction of copaibo oil (Figure 1(a) and (b)). | 89 - 89 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | The existence of protected areas of differing classes, and the opportunity to create new ones on local scales, within the framework of the application of Ecosystem Approach principles, in particular of decentralization and decision�making at the lowest possible level, completes the mosaic of conservation schemes contributing to connectivity and integrity. The establishment of a departmental system for Santa Cruz of protected areas, which seeks to coordinate between national, regional and local levels, can produce excellent results as long as a legal normative framework and the political will exist to make it effective opera�tionally. Without a doubt, achieving this coordination will be crucial in ensuring connectivity and integrity, not only for the forest, but also between the linked ecoregions (Chaco, Pantanal, Amazon), as well as a climate change adaptation strategy based on healthy ecosystems. | 89 - 89 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Socio-ecological resilience and management models The Chiquitano Dry Forest was incorporated into the International Model Forests Network in 2005. As a Model Forest, it seeks to generate agreements between key actors to develop land and natural resource management, sustainable agricultural production, biodiversity conserva�tion, and the promotion of scientific and traditional knowl�edge. Despite successive planning efforts on the ecoregion scale (Ibisch, Columba and Reichle, 2002; Vides�Almonacid, Reichle and Padilla, 2007; FCBC, 2010), the governing structure, allowing for the coordination of strategies between different governmental levels and which is agreed on by all sectors involved, is still weak. The application of Ecosystem Approach principles, as a strategy developed by the Convention on Biological Diversity, continues to present a big challenge for meeting the Model Forest objectives in the Chiquitano Dry Forest. | 89 - 89 | Prot-Adapt-Mitig- | INTANBILE | |
| Adapting to Change (2011) | However, the need to ensure the socio-ecological resilience of this tropical forest is becoming increasingly obvious, in view of not only climate changes but also political, economic and cultural changes which are felt ever more forcefully in the region. The participation of local actors, the creation of capacities, and the boost in land management and natural resource capabilities, as a step towards the establishment of collaborative approaches and planning for future development options, constitutes the main path towards maintaining the ecosystem services at landscape level (McAfee et al., 2010). Furthermore, given that biodiversity increases the resilience and resistance of forest ecosystems that are facing the changes, its conservation should be a core element of any management model applied to the terrain (Thompson et al., 2009). | 89 - 89 | Prot-Adapt-Mitig- | INTANBILE | INDG |

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| Adapting to Change (2011) | Case Studies – On Connectivity 93 4 Serrania de Santiago © Hermes Justiniano<br>The complex mosaic of usage rights in the Chiquitano Dry Forest region (as shown in Figure 1), provides a platform from which initiatives like REDD+ can be developed, as well as other actions that strengthen conservation and natural forest management units. With this in mind, it becomes necessary to:<br>• Consolidate existing protected areas (national as well as regional and local), through effective administration, providing them with legal security and sufficient staff, and adequately preparing and equipping them with realistic and viable management plans. | 89 - 90 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | • Integrate new sustainable forest management approaches – driven by the national government of Bolivia, in which greater control is given to local commu�nities with reference to the business efforts in the region – while searching to increase voluntary forest certification mechanisms that contribute to a fairer distribution of the economic benefits resulting from forest exploitation. | 90 - 90 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | • Boost the management of non-wood resources as an alternative and/or complement to the use of native tree species, which socially and economically justifies the maintenance of large areas of forest, as is the case in the Copaibo Reserve (Figure 1(a), orange polygon to the north). | 90 - 90 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | • Promote the implementation of existing instruments for planning and land management, on regional, municipal, indigenous and private scales, as a valid and technically supported strategy for land use and territorial occupa�tion, which considers and strengthens connectivity options either through maintaining environmental ease�ment or by boosting protected forests, private reserves or new local area (municipal or community) networks. | 90 - 90 | Prot-Adapt-Mitig- | | INDG |
| Adapting to Change (2011) | • Establish an effective governance platform between actors and sectors directly involved in the land manage�ment of the Chiquitano Dry Forest and management of its natural resources within the framework of the Model Forest management model, using the applica�tion of the Ecosystem Approach principles as a guide to its development. | 90 - 90 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | 94 4 Adapting to Change – The State of Conservation of World Heritage Forests in 2011 Tabebuia trees flowering © Hermes Justiniano<br>Concluding remarks In this context, adaptive management as 'active learning' is established as a real paradigm for creating an effective and creative management model against the backdrop of global changes in the Chiquitano Dry Forest. Thus, we must learn more about REDD+ mechanisms on a sub�national scale (in the sense of Angelsen et al., 2008), the coordination of sustainable exploitation models for wood and non-wood resources, the implementation of land-use planning on multiple scales, the effective management of protected areas, and the monitoring of biodiversity as they will be determining factors in maintaining large areas of protected forests, connecting wildlife corridors, and the provision of products and ecosystem services to society. | 90 - 91 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | In this sense, the Chiquitano Dry Forest provides an ecore�gional platform where approaches and ecosystem management models are put to the test, given the context of growing difficulties and threats that require rapid and effective learning and adaptation. | 91 - 91 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | Considering World Heritage sites – and taking into account the Noel Kempff Mercado National Park in partic�ular – the need to significantly improve the coordination of governance levels and decision-making becomes clear, as does the need to capitalize on lessons learnt and promote new management models. Presently, under the exclusive responsibility of the National State, there are deficiencies in regional (departmental) and local (municipal) govern�ment participation and from other civil society organiza�tions necessary for its management and conservation. A few years ago, the shared (public-private) administration management model for the national park allowed a reasonable balance between investments and manage�ment results, for which new contexts of consent and participation should be sought within the framework of the Model Forest or other plural authorities with UNESCO involvement. In this way, a World Heritage site and a Climate Action Project area could be preserved in perpe�tuity as a reference for REDD+ initiatives and as an example of integration on the different geographic and jurisdiction scales. | 91 - 91 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | World Heritage Forest meeting, Berastagi (1998) This compilation was developed during the 1998 Berastagi meeting (Indonesia) in 1998 that concentrated exclusively on tropical forests with a potential for inscrip�tion onto the World Heritage List. The concluding state�ment acknowledged that tropical forests were already fairly well represented on the List. However, gaps could still be identified and the Convention should therefore aim for a truly representative 'network' of tropical forests under World Heritage protection. Participants not only suggested potential new forest sites but also recom�mended that the World Heritage Centre prioritize the management of existing sites, hence ensuring the mainte�nance of their Outstanding Universal Value. | 106 - 106 | Prot-Adapt-Mitig- | | |

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| Adapting to Change (2011) | Expert Meeting on Boreal Forests, St.Petersburg (2003) In 2003, an expert meeting was held in St. Petersburg (Russian Federation) with the objective of identifying boreal forests with the potential for inscription onto the World Heritage List. This initiative mainly involved four countries: Canada, Finland, Norway and Russia. The expert group highlighted the great threat boreal ecosystems faced due to industrial activities and climate change, and reminded the international community of the great urgency concerning their protection. The panel made several recommendations to the World Heritage Centre, States Parties, site managers and IUCN, and identified a list of twelve potential new sites, five proposals for expan�sions, and seven sites warranting further evaluation. | 106 - 106 | Prot-Adapt-Mitig- | | |
| Adapting to Change (2011) | When World Heritage forest sites coincide with Ramsar sites or Biosphere Reserves, there may be opportunities to leverage additional support for conservation efforts by tapping into either the constituencies of the corresponding Convention or programme, or by strengthening an argu�ment for conservation measures under consideration. To this end, providing a ready list of World Heritage forest sites that coincide with Ramsar sites and/or Biosphere Reserves can serve as a tool to facilitate the work of World Heritage forest conservation stakeholders. | 107 - 107 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Factoring climate change into management of the World Heritage properties has many other benefits. Conservation of heritage will also increase the resilience of human communities to the impacts of climate change, for example through ecosystem services that World Heritage sites provide. Many World Heritage sites serve as natural buffers against climatic impacts and other disasters, or play a major role in climate change mitigation by reducing climate-altering carbon dioxide emissions in the atmosphere. | 5 - 5 | Prot-Adapt-Mitig-Impact | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | The World Heritage Centre has since endeavoured to provide support to States Parties and site managers in tackling climate change threats, for example through field projects in Peru (Manú National Park) and Indonesia (Tropical Rainforest Heritage of Sumatra), as well as the publication of Climate Change and World Heritage – Report on predicting and managing impacts of climate change on World Heritage and Strategy to assist States Parties to implement appropriate management responses,1 the Policy Document on the Impacts of Climate Change on World Heritage Properties, 2 and the compendium of Case Studies on Climate Change and World Heritage.3 This Practical Guide is an additional output from the World Heritage Convention's secretariat. We hope that it will be a good resource tool for World Heritage site managers interested in understanding how to respond to climate change, along with the climate change publications mentioned above. | 6 - 6 | Prot-Adapt-Mitig-Impact | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | A key challenge in producing this guide was to define its scope – many of the suggested activities may not be obviously linked to climate change, and it is for the manager to make those links where appropriate. However most, if not all, protected area and natural resource management challenges can be linked to climatic factors. For example, conflicts over natural resources such as land, food, shelter and water can usually be linked to stresses caused by drought, flooding, erosion or disease, which are generally climate-driven. Therefore we have interpreted climate change adaptation in this guide quite broadly. | 9 - 9 | Prot-Adapt-Mitig-Impact | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | A logical approach While management planning is not necessarily a chronological process, it is important to work systematically, first by trying to understand likely future climate change scenarios and by understanding how the OUV of a site might be affected by such conditions – this will depend on assessing vulnerability of the features that contribute to its OUV, linked to the implications of a range of climate scenarios. Some features may be more vulnerable to certain climate change impacts than others. | 10 - 10 | Prot-Adapt-Mitig-Impact | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | When designing adaptation strategies, it is crucial that climate change responses are gender aware, ensuring that women and men have an equal voice in decision-making on climate change and equal access to the resources necessary to respond to its negative effects. | 14 - 14 | Prot-Adapt-Mitig-Impact | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | In 2007 the IPCC presented its Fourth Assessment Report.8 The report confirms that climate change is occurring now, mostly as a result of human activities (Figure 1). It illustrates the impacts of global warming already under way and to be expected in future, and describes the potential for adaptation of society to reduce its vulnerability. It also presents an analysis of costs, policies and technologies intended to limit the extent of future changes in the climate system. Some of this information has already been summarized in the previous climate change publications of the World Heritage Centre (see preface). The IPCC Fifth Assessment report will be completed in 2014. | 17 - 17 | Prot-Adapt-Mitig-Impact | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | 5) Many solutions risk being expensive trials by error. All attempts at management on the ecosystem scale are expensive, complex and prone to some degree of failure, and it may be impossible to go back and try again, because the underlying conditions such as temperature or precipitation patterns are also changing. | 18 - 18 | Prot-Adapt-Mitig-Impact | | |

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| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | The capacity of World Heritage site management to adapt to climate change is determined by a number of activities taking place in the surrounding landscape. All protected areas have a spatial relationship with their surroundings, and exist within their wider ecosystems. A range of activities and requirements beyond the site will have a profound impact on its viability. Therefore, successful adaptation depends on the capacity of site managers to reconcile these different demands. | 19 - 19 | Prot-Adapt-Mitig-Impact | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | A consistent approach to documenting, recording and reporting the attributes of your site's key features will provide the basis for future impact assessment, as well as the basis for designing and implementing adaptation strategies. | 27 - 27 | Prot-Adapt-Mitig-Impact | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Extent and distribution of each species Reproduction rates and processes Grazers/browsers – species and distribution Presence of competing vascular species – rates of encroachment and loss Precipitation, temperature Site feature 9 Attributes (for each endemic landbird) Cloudey Island petrel Population size – numbers of pairs – dispersal Breeding sites – location, number Breeding rates – how often, how many Predation rates – native and non-native predators Competitors – native and non-native competitors Death rates – ageing, accidental death, exposure to disease Frequency of storm events/wind conditions Temperature, precipitation Feeding – locations, food species, habitats The above attributes should be monitored because they provide the basis for evidence of any changes that may be linked to climate factors, and therefore how the OUV might be negatively impacted. The managing team needs to consider how to consistently measure these attributes and how to present the results, in order to assess the condition of each feature and whether it is declining, stable or improving. The Operational Guidelines recommend site managers to identify 'key indicators for measuring its state of conservation'. | 29 - 29 | Prot-Adapt-Mitig-Impact | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Worksheet 3: Features and attributes – objectives Features Attributes Objectives FEATURE A B C D FEATURE A B C D FEATURE A B C D<br>33 Planning for adaptation 3 3.3 Assess your site (3) – understand its sensitivity and vulnerability It is important to remember that your site may contribute significantly to mitigating the effects of climate change – tropical forests, salt marshes and mangroves, sea grasses and peat uplands store large quantities of carbon, and most of them also serve as refuges and pockets of biodiversity that retain metapopulations, and in some cases act as natural protective barriers to climate-related physical impacts and other effects such as diseases. Moreover, as World Heritage sites are usually the largest, and often among the best�conserved within a local or regional network of protected areas, they can act as a centre of species dispersal to smaller protected areas, contributing to biodiversity conservation throughout a broader landscape. In this way, your site can play an important climate change adaptation role for the larger protected areas network. | 30 - 31 | Prot-Adapt-Mitig-Impact | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Protected areas also serve as natural buffers against climate impacts and other disasters, providing space for floodwaters to disperse, stabilizing soil against landslides and blocking storm surges. It has been estimated that coastal wetlands in the United States provide US$23.2 billion a year in protection against flooding from hurricanes. | 31 - 31 | Prot-Adapt-Mitig-Impact | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Natural Solutions: Protected areas helping people cope with climate change (Dudley et al., 2010) Outstanding Universal Value Sensitivity, Vulnerability, Resilience Features and attributes Capacity to adapt Context – World Heritage, climate change Climate change scenarios Potential options Assessing risk Implementation logistics Prioritizing action Monitoring and evaluation Emerald Lake, Canadian Rocky Mountain Parks (Canada). © Maureen Flynn<br>34 3 Planning for adaptation boundaries may be too porous to maintain integrity in the face of encroachments of many kinds – extraction, pollution, settlements, poaching and so on. A site may be particularly sensitive if it is a rare or unique type of habitat, or if it is isolated from similar sites. In Section 3.4 we ask 'how resilient is your site?' A sensitive site may be the opposite of a resilient site, as demonstrated by the examples given. | 31 - 32 | Prot-Adapt-Mitig-Impact | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Lack of corridors and buffer zones results in the inability of species to migrate and find new breeding and feeding grounds, and can result in loss of key species and ultimately a breakdown in habitat.<br>36 3 Planning for adaptation Example 8. Monitoring the attributes of the endemic Cloudey Island petrel. | 33 - 34 | Prot-Adapt-Mitig-Impact | | |

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| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Human-induced fires are having an impact on important flora. Two of the lakes were stocked with non�native fish about seventy years ago, which may pose a threat to the native species, although the trends are not known. 37 Planning for adaptation 3 In conclusion, climate change vulnerability indicates the extent to which changes in climatic conditions are likely to cause a negative impact to the site’s OUV. This is determined by: off-site stresses (e.g. future climate projections, surrounding landscape scale influences); on-site conditions (e.g. current state of conservation of rare species); and adaptive capacity (e.g. ability of management to take action to prevent negative outcomes). | 34 - 35 | Prot-Adapt-Mitig-Impact | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Outstanding Universal Value Sensitivity, Vulnerability, Resilience Features and attributes Capacity to adapt Context – World Heritage, climate change Climate change scenarios Potential options Assessing risk Implementation logistics Prioritizing action Monitoring and evaluation Tajik National Park (Mountains of the Pamirs) (Tajikistan). © Nomination file 40 3 Planning for adaptation Management systems The questions in Worksheet 4, adapted from the resource manual on Preparing World Heritage Nominations, 24 relate to management systems, and should be helpful in assessing vulnerability to climate change linked to site management. | 37 - 38 | Prot-Adapt-Mitig-Impact | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | General level of knowledge of the site Extensive Good Some knowledge Limited None General level of support for the site and its aims Negative Positive -5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5 Particular areas of concern (if any) or opportunities for engagement Lack of trust? Past problems? Open antagonism? Breakdown in communication? Disagreements over rights? Etc. 42 3 Planning for adaptation Legal and policy context The ability to manage any World Heritage site (and to adapt to climate change impacts) will depend on the legal and policy support given by government, especially in relation to legal and policy issues that may potentially impact on a site’s integrity, as well as the documentation that establishes its legal status. Additionally, many countries also have national strategies, policies and other legislation on climate change of which the site management should be aware. | 39 - 40 | Prot-Adapt-Mitig-Impact | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Build alliances with NGOs, businesses and landowners. Work with them to raise awareness of climate change. Work with adjoining landowners to enhance positive management and minimize negative impacts – encourage the control of pesticides, herbicides and fertilizers, especially where your site is ‘downstream’ of such land; encourage the naturalization of waterways and their shorelines. | 43 - 43 | Prot-Adapt-Mitig-Impact | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | http://www.indiawaterportal.org/; http://whc.unesco.org/en/ list/798 Expand the effective size of the site, by introducing a buffer zone if possible, in order to allow for movement and population growth. Encourage sustainable use/ alternative livelihoods with surrounding communities in the area, so as to minimize impacts on adjoining ecosystems. Where feasible, secure formal agreements for co-management of resources. | 43 - 43 | Prot-Adapt-Mitig-Impact | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Given that the site is also subject to coastal erosion, it is particularly important that clear, agreed national and local policies are harmonized and rigorously applied in order to protect its OUV in the context of the wider landscape. Various planning, coastal protection, agriculture, floodwater and access laws are used to regulate activities and to establish and enforce protective policies. | 43 - 43 | Prot-Adapt-Mitig-Impact | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | 3.7 Key issues in adaptation planning 1. Ensure that you take into account the dynamics of climate change when developing management plans. You will need to consider the possible effects of sea level rise, increased storm incidents, flood events, drought, glacial retreat, etc. These may include change in land cover, habitats and species; erosion and silting up; or changes in migration patterns. You may therefore need to plan for coastal realignment; diversion or blocking of watercourses; expansion or reshaping of your site; or relocation of any settlements away from threatened valleys or coasts. Your plan should demonstrate that you have thought about these things and considered a range of options. Do not produce plans as if there will be no changes to your site over the next decades. | 45 - 45 | Prot-Adapt-Mitig-Impact | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Rezoning the Great Barrier Reef In 2004 the Australian Government rezoned the Great Barrier Reef to increase protection to a range of species and resources. For example, the ‘no take’ areas were increased from 5 to 33 per cent, and ‘no trawl’ areas from 15 to 28 per cent of the park. One of the main reasons was the protection of the marine turtle, which had suffered from various impacts including fishing. Overall, the area that provided increased protection for the three marine turtle species from trawling rose from 30 to 70 per cent. | 45 - 45 | Prot-Adapt-Mitig-Impact | | |

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| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | http://www.gbrmpa.gov.au/zoning-permits-and-plans/zoning<br>48 3 Planning for adaptation 2. Review the zoning system for your site. You may need to carry out interventions on parts of it, and allow for new patterns of movement and colonization by both humans and wildlife in and around the site. If applicable, review the management of visitors to reduce erosion, waste, disruption, litter and other impacts. | 45 - 46 | Prot-Adapt-Mitig-Impact | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Outstanding Universal Value Sensitivity, Vulnerability, Resilience Features and attributes Capacity to adapt Context – World Heritage, climate change Climate change scenarios Potential options Assessing risk Implementation logistics Prioritizing action Monitoring and evaluation<br>50 3 Planning for adaptation Climate predictions for a specific site should be seen as a way to develop a context, or as a way to understand how significant the issue might be. Although we do not have the capability to change future climatic conditions, being forewarned gives a context for scenario-building, which in turn allows possible responses to be planned. | 47 - 48 | Prot-Adapt-Mitig-Impact | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | While future climate conditions are very difficult to predict precisely, even rough predictions will help a manager to think about the ways in which the attributes of the OUV may be expected to respond to future climate conditions. This allows at least some form of risk analysis as the basis for designing an adaptation plan. Such a plan should provide a range of prioritized actions, both within and beyond the site itself. | 48 - 48 | Prot-Adapt-Mitig-Impact | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Coasts will be exposed to increasing risks such as coastal erosion due to climate change and sea-level rise Increases in sea-surface temperature of about 1–3 °C (will) result in more frequent coral bleaching events and widespread mortality unless there is thermal adaptation or acclimatization by corals' Increased exposure to higher turbulence from the sea Changes to marine biology Increased exposure of plateau scrub to salt spray Changes to reef pattern Increased exposure of beach to rising sea levels and turbulence Increase in tropical storm events Accelerated undermining of cliffs and caves Loss of prey species Loss of endemic invertebrates Coral bleaching Disruption to turtles nesting on the beach Loss of habitat and associated species 'More and larger glacial lakes' 'Increasing rock avalanches ...' 'Increased run-off and earlier spring peak discharge in many glacier and snow-fed rivers' 'Changes affecting algae ... fish and zooplankton because of rising water temperatures and changes in: ice cover, oxygen levels, water circulation' 'Dry regions will get drier, and wet regions will get wetter' 'Spring events such as the unfolding of leaves, laying of eggs and migration are happening earlier' '...pole-ward and upward (to higher altitude) shifts in ranges of plants and animal species' Shorter periods of freezing Increased avalanche events Wetter conditions in some areas Changes to lake biology, as a result of increased eutrophication Drier, hotter conditions in high plateau areas Changes in habitat – loss or migration of some plant communities Increased silting downstream Catastrophic flooding as a result of glacial dam bursts New lakes formed from avalanche debris Increases in algal blooms Disruption to feeding/ breeding habits of key mammal species Loss of feeding grounds/ refuge sites for migrating birds Migration of prey species Increases in uncontrolled fire events<br>52 3 Planning for adaptation Example 10. Problem tree analysis. | 49 - 50 | Prot-Adapt-Mitig-Impact | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Hotter, drier conditions on plateau Loss of plant cover Loss of pollinating insects Increased number of uncontrolled ffres Changes in habitat structure Exposure and erosion of soils Incapacity of ffora to recover Loss of critical ffora Out-migration of herbivores Loss of key predators Increased water run-off Downstream impacts Rough predictions such as the above will help a manager to think about the ways that the attributes of the OUV may be expected to respond to future climate conditions (i.e. a risk analysis). The risk analysis forms the basis for designing an adaptation plan, which should relate to a spatial hierarchy of actions, both within and beyond the site itself (see Section 3.10 on adaptive actions). | 50 - 50 | Prot-Adapt-Mitig-Impact | | |

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|---|---|---|---|---|---|
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | http://www.metoffice.gov.uk/precis/ 53 Planning for adaptation 3 3.9 Understand likely OUV responses – analyse the risks A useful way of analysing the risk to a site's OUV is to look at its key features and their attributes and assess the probability and significance posed by threats. For example: OUV feature Description of impact Reptile community of the site is among the most diverse in the world, with more than thirty-five species, 90 per cent of which are endemic Invasive predator damages populations Increased fire frequency changes vegetation, reducing habitat Reduced precipitation results in loss of wetland habitat Increased storm frequency and intensity results in eroded and sediment-laden habitats Phenology of spring grasses alters food for major prey during breeding season OUV feature Description of impact Probability Significance Reptile community Invasive predation on reptiles Fire frequency degrades habitat Precipitation frequency causes loss of wetlands Storm frequency and intensity damages habitats Phenology of spring grasses alters food for major prey during breeding season Improbable (low) Insignificant (low) Possible (medium) Significant (medium) Probable (high) Highly significant (high) Outstanding Universal Value Sensitivity, Vulnerability, Resilience Features and attributes Capacity to adapt Context – World Heritage, climate change Climate change Potential scenarios options Assessing risk Implementation logistics Prioritizing action Monitoring and evaluation Obviously the less resilient a site is, and therefore the more vulnerable it is to climate change, the higher the risk that it will suffer negative impacts from changes in climate. For the manager, the task is first to identify the sources of those risks, then to determine: – How likely are they to occur? | 50 - 51 | Prot-Adapt-Mitig-Impact | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Some events might be highly likely, but not significant to the OUV of a site. Others might be highly unlikely but disastrous if they do occur. A risk analysis is designed to help to identify outcomes that would be both relatively likely and relatively significant, and would therefore demand priority management attention. 54 3 Planning for adaptation In this example the site manager will focus efforts on improving capacity to manage fire in specific areas where damage to reptile habitat is most likely, while establishing a rigorous monitoring programme for the presence of invasive species. | 51 - 52 | Prot-Adapt-Mitig-Impact | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | An analysis of this sort allows the manager to identify key actions to sustain the OUV. Risk assessment is not a perfect science – it is informed guesswork based on the intuition, insights and expertise of the management team and colleagues, but it does provide a basis for focusing on issues that might otherwise be missed. This kind of assessment is therefore always most effective when carried out by a team that understands socio-economic as well as ecological dimensions. | 52 - 52 | Prot-Adapt-Mitig-Impact | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Outstanding Universal Value Sensitivity, Vulnerability, Resilience Features and attributes Capacity to adapt Context – World Heritage, climate change Climate change scenarios Potential options Assessing risk Implementation logistics Prioritizing action Monitoring and evaluation Example 11. Prioritizing management actions at Cloudey Island. | 53 - 53 | Prot-Adapt-Mitig-Impact | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | The Cloudey Island management team has assessed the risks to two of the features that contribute to their OUV, and then considered their possible responses against a set of criteria. They have also considered whether there are likely to be any conflicts between their responses and other features and attributes that contribute to the OUV. | 53 - 53 | Prot-Adapt-Mitig-Impact | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | The risk from climate refugees is not seen as an immediate threat, but it is a possibility, and work needs to be done to minimize this risk. 57 Planning for adaptation 3 Worksheet 9: Prioritizing action against criteria Possible response actions Criteria Priority actions 3.11 Implement your plan This section deals with some of the practicalities of implementing your responses. Much of this should be familiar in the context of management and action planning. | 54 - 55 | Prot-Adapt-Mitig-Impact | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Outstanding Universal Value Sensitivity, Vulnerability, Resilience Features and attributes Capacity to adapt Context – World Heritage, climate change Climate change Potential scenarios options Assessing risk Implementation logistics Prioritizing action Monitoring and evaluation 58 3 Planning for adaptation Example 12. Action plan and related tasks at Cloudey Island. | 55 - 56 | Prot-Adapt-Mitig-Impact | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Having listed the tasks linked to each option, the management team has now agreed on a logistical plan for implementing the tasks. It recognizes the need to start a training programme and to set up the system early on, and has timed its activities to coincide with appropriate seasonal factors such as breeding and rearing, different weather events, and optimal trapping times. It appreciates the need to minimize human presence on the island, and has timed monitoring activities to coincide with each other where possible, as this will also optimize logistics and minimize impact. | 56 - 56 | Prot-Adapt-Mitig-Impact | | |

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| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Monitoring small isolated ecosystems such as pools, wetlands, wooded areas and scrubland will assist in assessing ecosystem-scale impacts. These small systems contribute disproportionately to regional landscape diversity, have easily assessed communities and physical structure, and serve as stepping stones in the landscape, facilitating plant and animal movements.30 At the community and ecosystem scale, climate monitoring has also demonstrated rapid recent changes across a landscape. For example, alpine streams in Switzerland have warmed, shown reduced nitrogen concentrations and reduced taxa richness and density of zooplankton in only a few decades.31 30 L. de Meester et al., 2005, Ponds and pools and model systems in conservation biology, ecology and end evolutionary biology Aquatic Conservation: Marine and Freshwater Ecosystems, Vol. 15, pp. 715–25. | 58 - 58 | Prot-Adapt-Mitig-Impact | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | 36 http://www.bto.org/science/international/out-africa 37 http://www.birdlife.org/africa Outstanding Universal Value Sensitivity, Vulnerability, Resilience Features and attributes Capacity to adapt Context – World Heritage, climate change Climate change scenarios Potential options Assessing risk Implementation logistics Prioritizing action Monitoring and evaluation<br>61 Planning for adaptation 3 Where appropriate, managers of African World Heritage sites might focus on such migrations as indicators of climate change, partly because of the contribution such observations would make to global research but also because these data are not well known, so careful data collection might be especially informative. Likewise, larger migratory animals provide essential information on changes in seasonal vegetation patterns. Scientists have successfully associated animal migrations and insect emergences with fine-scale climatic patterns.38 Amphibian communities in particular have shown the most dramatic climate change responses to date.39 In one study, autumn breeding amphibian populations are breeding later and winter breeding species are breeding earlier, with changes ranging from 5.9 to 37.2 days per decade.40 38 D. Senepathi et al., 2011, Climate change and the risks associated with delayed breeding in a tropical wild bird population, Proceedings of the Royal Society Part B – Biological Sciences, Vol. 278, pp. 3184–90. | 58 - 59 | Prot-Adapt-Mitig-Impact | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | As described in Tool 11 of Enhancing our Heritage Toolkit, monitoring and assessment can help the site team to clarify its perception of climate change risks, its adaptive strategy, and the effectiveness of the adaptation actions it has decided to implement. As part of designing an effective assessment, the team will need to develop a range of indicators to measure the key outcomes from the adaptation plan; these should be directly related to the attributes of the site OUV. | 59 - 59 | Prot-Adapt-Mitig-Impact | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Source: National Academy of Sciences (2002), http://www.pnas.org/content/99/21/13379<br>3 Planning for adaptation 62 Monitoring is always limited by available resources, so the results and interpretations of a monitoring programme should be framed appropriately. For example, the experimental design (i.e. kinds and numbers of samples collected at various places and times) will dictate how well the site team understands the natural variance and the effects of an intervention such as an adaptation practice. Monitoring results might be phrased as statistically significant differences or as differences observed and recorded anecdotally. It will usually be valuable to consult a statistician, perhaps through a local university or ministry office, to assist with design and interpretation of monitoring results. | 59 - 60 | Prot-Adapt-Mitig-Impact | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | However, at regular timepoints during a programme, the management team should periodically pause and reflect on how effectively the site is being managed as well as how clearly the team understands the effects of its management. | 62 - 62 | Prot-Adapt-Mitig-Impact | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | As well as evaluating the effects of any climate change adaptation strategy, it is important to recognize the need to evaluate the monitoring programme itself. Managers need to ensure that monitoring has been systematic, objectively verifiable, appropriately timescaled, adequately resourced, efficiently carried out and targeted at measurable and relevant indicators. | 63 - 63 | Prot-Adapt-Mitig-Impact | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Worksheet 11 summarizes a range of climatic factors and approaches to recording them. It is generic, not comprehensive, and requires adaptation to local circumstances, but may be a useful starting point in recording climate patterns and effects over the following decades. | 63 - 63 | Prot-Adapt-Mitig-Impact | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Application Deadline Varied Amount Varied URL Link http://www.thegef.org/gef/ The Adaptation Fund Eligibility Country Eligibility Developing country Parties to the Kyoto Protocol that are particularly vulnerable to the adverse effects of climate change including low-lying and other small island countries, countries with low-lying coastal, arid and semi-arid areas or areas liable to floods, drought and desertification, and developing countries with fragile mountainous ecosystems. | 74 - 74 | Prot-Adapt-Mitig-Impact | | |

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| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Water quantity and quality at Ichkeul is crucial to ensure a wetland ecosystem suitable for the migratory birds. The site lies at the bottom of a watershed and is separated from the sea via a small waterway leading to a salt lagoon. For this reason, the wetland's salinity is affected by the volume of water flowing into it. In the summer, salinity increases as water inflow decreases. In the winter, the reverse holds true – resulting in a delicate balance which provides suitable habitat quality for migratory birds. However, during prolonged Ichkeul National Park (Tunisia). © UNESCO/Marc Patry 84 6 Appendices droughts, and as sea levels rise, more sea water invades the wetland, increasing salinity to the point of having a detrimental impact on habitat quality. Compounding the challenges faced by the management agency, upstream capture and diversion of freshwater is increasingly an issue. The water is used to meet the needs of Tunisia's capital city, Tunis. | 80 - 81 | Prot-Adapt-Mitig-Impact | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | In this respect, a climate change mitigation project in the lands abutting the western boundary of this site may help to avoid a future scenario whereby local communities are compelled to turn to the World Heritage site for subsistence, thus undermining its Outstanding Universal Value. The Kariba REDD+ (United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries) project, certified under recognized international carbon verification standards, is selling carbon credits and funds are being applied to help communities improve agricultural practices, stabilize land use, and restore degraded forests. In so doing, the project will be improving the resilience of the World Heritage site, reducing the risk of incursions from surrounding communities in an age of climate change – when droughts are expected to be more common and severe. The project will also strengthen the connectivity of the site to the broader landscape, further supporting site resilience. | 82 - 82 | Prot-Adapt-Mitig-Impact | | INDG |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | The World Heritage Centre has developed this practical guide to assist those responsible for the management of natural World Heritage sites to better understand how climate change may affect those features of the site that contribute to its Outstanding Universal Value and offer ideas for identifying options for adapting to climate change with tailored management responses. The purpose is to ensure the World Heritage site's resilience in the face of climate change, and therefore to sustain its Outstanding Universal Value. | 5 - 5 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | This guide helps site managers to analyse climate change threats and how they are likely to influence management objectives. It should enable site managers to factor climate change into management and action planning and feed into an existing management plan where one is already in place (e.g. | 9 - 9 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Other uses of such a plan might include making bids for funds and clarifying how those funds might be used, or taking opportunities to tap into funds from current programmes in national land planning, management planning or climate change. | 9 - 9 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Other guides, especially UNESCO World Heritage Centre's Enhancing our Heritage Toolkit, 4 can be useful where climate change concerns need to be integrated into wider management considerations. | 9 - 9 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | The purpose of management in this context is to ensure the World Heritage site's resilience in the face of climate change, and therefore to sustain its Outstanding Universal Value (OUV). | 9 - 9 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Most of the elements described in this guide are identical to management planning processes, and they should be used alongside the production of a management plan where possible, to avoid unnecessary costs and duplication. Where an up-to-date management plan is in place, much of the data and thinking may already exist, and need not be repeated. | 9 - 9 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Think in terms of a 'toolbox' of adaptation practices rather than single solutions. These should apply across a range of spatial and temporal scales. | 10 - 10 | Prot-Adapt-Mitig- | | |

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| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | On the other hand, a convincing, evidence-based plan for adaptation will provide a strong case for funding. | 10 - 10 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | 5 For a guide to performing a problem tree analysis, see FAO, 2002, Community-Based Forest Resource Conflict Management, Training Package, Section 9.2, Exercise 8, Rome, Food and Agriculture Organization of the United Nations. | 10 - 10 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | http://whc.unesco.org/en/guidelines/ Table 1: Explanation of key terms Term Meaning Example Outstanding Universal Value (OUV) A natural site is considered to have OUV when it: (i) meets one or more of the four natural heritage criteria (see p. 24), (ii) satisfies conditions of integrity and/or authenticity, and (iii) has an adequate protection and management system to ensure its safeguarding. | 12 - 12 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | A site that contains a globally rare, endemic species, and thus provides it with the refuge, feeding and breeding conditions that sustain its population, could be said to have OUV provided its integrity can be maintained and it is effectively protected by legislation and effective management. | 12 - 12 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Wetlands may be a feature of a larger management area. But within a wetland there may be features such as pools, wet scrub, bogs, reed marsh and so on. | 12 - 12 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | At the end of a programme, or periodically, an organization might assess what activities have been carried out, what results have been achieved (outputs) and at what cost (inputs) in order to assess their effectiveness. Evaluation is also a review tool for management. | 13 - 13 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | We recognize that cooperation with communities neighbouring World Heritage sites is crucial in the implementation of adaptation strategies. In this respect, those responsible for identifying and implementing these strategies should also consider their community and gender-related implications. Every effort should be made to ensure participation of local and indigenous communities in climate change decision-making so that adaptation strategies contribute to the well-being of the communities, including marginalized groups, and avoid strengthening existing inequalities. Knowledge possessed by indigenous peoples also contributes to climate change assessment and adaptation by offering observations and interpretations at a much finer spatial scale with considerable temporal depth and by highlighting elements that may not be considered by climate scientists. | 13 - 13 | Prot-Adapt-Mitig- | | INDG |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | There is a growing body of work on climate change and gender. A short list of useful resources is provided below: Gender Climate Change platform for information, knowledge, and networking on gender and climate change. http://www.gendercc.net/ Global Gender and Climate Alliance – Incorporating a gender perspective in all climate change policies and initiatives. http://www.gender-climate.org/ González, A. M. and Martin, A. S. 2007. Gender in the Conservation of Protected Areas. Parks in Peril, Innovations in Conservation Series. Arlington, Va., The Nature Conservancy. http://www.cbd.int/doc/pa/ tools/Gender%20in%20the%20conservation%20 of%20protected%20areas.pdf IUCN, UNDP, GWA, ENERGIA, UNESCO, FAO and WEDO as part of the Global Gender and Climate Alliance (GGCA). 2009. Training Manual on Gender and Climate Change. San José, Absoluto. https://portals.iucn.org/ library/efiles/documents/2009-012.pdf UNDP. 2013. Africa Adaptation Programme Experiences: Gender and Climate Change. New York, United Nations Development Programme. | 14 - 14 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | To be inscribed on the World Heritage List, a site must have Outstanding Universal Value (OUV). OUV implies 'cultural and/or natural significance which is so exceptional as to transcend national boundaries and to be of common importance for present and future generations of all humanity. As such, the permanent protection of this heritage is of the highest importance to the international community as a whole.' (UNESCO World Heritage Centre, 2013, para. 49). | 16 - 16 | Prot-Adapt-Mitig- | | |

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| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | States Parties to the World Heritage Convention have the responsibility to ensure the identification, nomination, protection, conservation, presentation, and transmission to future generations of the cultural and natural heritage found within their territory. All properties inscribed on the World Heritage List must have adequate long-term legislative, regulatory, institutional and/or traditional protection and management to ensure their safeguarding. This guide can help countries to carry out some of these obligations. | 16 - 16 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | 6) There are no obviously recognizable alternative solutions that are better. There may be many possible solutions, some already tried elsewhere, some not yet identified. By its nature, adaptation is about trial and error, using emerging knowledge, understanding, creativity and judgement based on experience. | 18 - 18 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Think beyond the spatial boundary Address the site in its broader landscape (Figure 3). The most successful climate change adaptation strategies view the site as an element of a larger landscape and then address the OUV on-site in the context of off-site practices that influence the OUV. | 19 - 19 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Climate change adaptation requires analysis of the current situation and the projected changes, measuring the results of actions taken, revising them and trying again. Adaptive management is based on this cycle of analysis, application, evaluation and revision (Figure 4). | 19 - 19 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Hydro dam Settlements Settlements<br>22 2 Understanding the context Approach the problem at different levels using different methods Adaptation responses take place at different levels. Small, site-specific, lower-level actions can be taken on most sites. | 19 - 20 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Cloudey Island meets criterion vii – it contains superlative natural phenomena and areas of exceptional natural beauty and aesthetic importance. The island also meets criterion x, as it contains the most outstanding and significant natural habitats for in situ conservation of biological diversity, including threatened species of Outstanding Universal Value. | 23 - 23 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Does the site have a buffer zone? If so, is it under any threat?<br>28 3 Planning for adaptation All World Heritage sites should have a Statement of Outstanding Universal Value (SOUV). Because it is impossible to list and describe every possible element of sites, these statements try to summarize those aspects that provide the foundation for World Heritage status (see Example 4). | 25 - 26 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Many resources are available for support in documenting natural conditions. Enhancing our Heritage Toolkit, 14 especially Tool 1, 'Identifying site values and management objectives', is particularly useful in understanding this step. | 26 - 26 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | This can be a difficult concept to grasp, but it is central to effective site management. What counts as a feature depends on the spatial scale of a site. Some large areas may have few features, while other areas may have many. The best way to consider features is to simply list those things that are considered most important. The OUV statement will help you to identify them. | 27 - 27 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | 1) Fossil raised reef 2) Karst cliffs, caves and pinnacles 3) Reef fish species 4) Natural scrub forest 5) Ten species of endemic vascular plants (1–10 listed) 6) Invertebrate species 7) Reptiles/turtles 8) Seabirds 9) Four species of landbird including the Cloudey Island petrel (1–4 listed) These are fairly general, and in the case of Cloudey Island only one specific species was named as a feature in the site's Statement of OUV – the Cloudey Island petrel. Good management dictates that as far as possible all species that constitute a key feature are listed, but this depends on the capacity of the management staff. | 28 - 28 | Prot-Adapt-Mitig- | | |

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| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Site feature 4 Attributes Natural scrub forest Extent and distribution Canopy cover – percentage of closed/open canopy Species composition – relationship between different indigenous species/indigenous�introduced species Regeneration – rate of regeneration/growth/death for each species Dead wood – abundance of standing and fallen dead wood Understorey and ground flora – abundance and composition of species at different levels Precipitation, temperature, frequency of storm events, wind conditions In order to monitor these features, each of their attributes must be understood (see Example 6). Attributes are what any feature needs to make it function, and which can be observed. These include feeding, sheltering, breeding, predation, migration patterns, and other factors such as hunting, pollution, etc. They might include extent, variety, age, extraction and regrowth rates for forests, or abstraction and recharging, biological and chemical composition in watercourses. All these attributes can be directly measured and observed, and will provide the evidence for managing change and responding to it.<br>31 Planning for adaptation 3 Site feature 5 Attributes (for each endemic vascular plant) Plant 1, 2, 3, etc. | 28 - 29 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | As well as providing the basis for monitoring pressures and trends, this systematic approach allows the manager to set clear objectives that can be monitored. The aim of managing any natural World Heritage site is to maintain and enhance its OUV, but this is meaningless unless clear objectives and management targets can be set (see Example 7 and Worksheet 3). | 29 - 29 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | In the case of extensive, remote natural sites exposed to few anthropogenic threats, the objectives may be relatively straightforward – perhaps no more than monitoring the attributes and reporting. Smaller more sensitive sites may require more intervention to maintain their integrity, and the objectives may need to reflect this. Some sites may include specific cultural and economic, as well as natural objectives, under different headings – you will need to ensure these do not conflict.<br>32 3 Planning for adaptation Example 7. The case of the Snowey Mountains System demonstrates the link between aims, features, attributes and management objectives. | 29 - 30 | Prot-Adapt-Mitig- | INTANBILE | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | For these reasons it is in everyone's interest to protect and enhance such sites. In this guide, sensitivity and vulnerability are seen as separate but linked concepts. A site may be sensitive for many reasons. It may be too small to resist a number of pressures; key species populations might be at critical levels with little room to manoeuvre, or its Value of protected areas for climate change mitigation and adaptation Protected areas play a major role in reducing climate�changing carbon dioxide emissions in the atmosphere. | 31 - 31 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Giant leaf frog, Amazon National Park – many amphibians have very specific climatic requirements and their populations change rapidly as climatic conditions change. Therefore, amphibians are often sensitive indicators of climate change. © Dawn Tanner and Jim Perry<br>35 Planning for adaptation 3 Table 2: Possible threats posed by climate change in different habitats/landscape types Habitat/ landscape type Possible threats High mountain range Glacial melt leads to inundation of valley habitats and communities. | 32 - 33 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Is there a protocol for government support should the need arise in the case of critical events?<br>41 Planning for adaptation 3 Stakeholders Adaptive capacity includes your relationship to the communities around you, without whose support effective responses to the threat of climate change would be impossible. You also need to understand your other partners and stakeholders – what motivates them, how they relate to the site, and their negotiating positions (see Worksheet 5). Different people and groups need different kinds of approaches – some will be less confident in large meetings, or may be unable to express their concerns. | 38 - 39 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Some may be hostile to World Heritage site management for complex reasons that are important to recognize. For a complementary worksheet on engagement of stakeholders, please see Enhancing Our Heritage Toolkit. | 39 - 39 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | It is therefore important to review how the government influences site management, by analysing its commitment through national laws, through the policies it promotes, and through the international laws, treaties and conventions it actively supports (see Worksheet 6). | 40 - 40 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Title Policies Relevance to OUV Title Statement/reference<br>43 Planning for adaptation 3 Site design Site boundaries are defined under the terms of the World Heritage inscription. However, they may not reflect the ecological patterns and systems that support ecosystem functions such as prevailing rainfall patterns, migration, hydrological systems, variations in habitat types, and so on. | 40 - 41 | Prot-Adapt-Mitig- | | |

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| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Many natural World Heritage sites are surrounded by a buffer zone that may be more or less under the control of the site management agency, and/or for which there may be specific land-use policies in place designed to support the integrity of the site. The existence, the size and design, and the actual management implications of buffer zones vary widely among sites. Ecological connectivity within the buffer zone and beyond is a crucial factor in the site's resilience – particularly for smaller sites (e.g. less than 10,000 ha). | 41 - 41 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | On their own, such interventions may not prove successful, and a raft of other initiatives may need to be taken. Some of these may entail paying or compensating surrounding communities to do or to avoid doing something that might influence the resilience of the site; optimizing people's interests in supporting the protection of wildlife and ecosystems by raising awareness of their values and by giving people a stake in their protection; persuading politicians or the private sector of the importance and expediency of protecting the OUV of World Heritage sites; and generating the support of the global community in the protection of such sites. | 42 - 42 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | In general, adaptation practices should conserve the geophysical stage, protect refugia, and promote connectivity within the greater landscape. Some interventions require hard engineering, such as artificial reefs, breakwaters, roads, canals, removing invasive species, re-vegetation, managing dunes, restoring wetlands, or burning. Others focus on changing human behaviour, such as education, zoning, taxation, legislation, or social programmes.25 Significant engagement with stakeholders in the surrounding land/ 25 See for example, A. Travers et al., 2012, Ecosystem-based Adaptation Guidance – Moving from Principles to Practice, Nairobi, United Nations Environment Programme. | 42 - 42 | Prot-Adapt-Mitig- | INTANBILE | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Work with national planning and development agencies to include conservation and enhancement of OUV in all policies and plans, including sustainable development strategies, spatial plans, requests for funding, action plans, district and regional development plans, poverty reduction strategies, etc. | 43 - 43 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Integrated protection of World Heritage The Canadian Government has integrated protection of World Heritage properties into comprehensive planning programmes. Where World Heritage sites are administered by Parks Canada, site authorities participate in land- and resource-use planning processes beyond the site's boundaries to ensure that the World Heritage values are recognized in spatial strategies. Where sites are owned by the provinces, municipal planning activities must take into account the values of the sites. Environmental assessment legislation is also widely used to ensure that alternatives and mitigation of threats are applied when considering proposals. | 43 - 43 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | http://www.jurassiccoast.com/downloads/spatial_planning_ research_project_-_luc.pdf South Africa has a national climate change response strategy (2004) containing twenty-two key actions including 'Develop protection plans for plant, animal and marine biodiversity'. | 43 - 43 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | http://unfccc.int/files/meetings/seminar/application/pdf/ sem_sup3_south_africa.pdf<br>46 3 Planning for adaptation Form alliances with managers of other natural World Heritage sites and protected areas within the area of influence of your site if possible, to ensure effective communication about migratory species such as birds, butterflies or large mammals. | 43 - 44 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Managing with fire The plant and animal communities of many arid and semi-arid landscapes have evolved to depend on fire. In these landscapes, fire removes or controls invasive plants, releases nutrients and opens certain kinds of seeds. Fires have been a natural part of ecosystem function for millions of years and part of human-induced management for thousands. The fire-adapted landscapes of South Africa, including Cape Floral Region (http://whc.unesco.org/en/list/1007) and Vredefort Dome (http://whc.unesco.org/en/ list/1162) World Heritage sites, are examples of such landscapes. Intentional fire management through controlled burns can serve to protect the OUV of these fire-dependent areas. | 44 - 44 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Focus on preserving and strengthening existing biological corridors.<br>47 Planning for adaptation 3 Hard engineering: Case of Mount Kenya Mount Kenya National Park hosts significant numbers of elephants, but much of the surrounding landscape is farmed. Kenya Wildlife Service, with the support of many partners including Kisima Farm, the Bill Woodley Mount Kenya Trust, the Ngare Ndare Forest Trust and the Lewa Wildlife Conservancy is increasing options for elephant movement in response to changing conditions. The most ambitious project has been a wildlife underpass, allowing animals to cross highways in safety. The underpass opened in January 2011 and has already proved to be beneficial to wildlife and in increasing connectivity to improve ecosystem resilience. | 44 - 45 | Prot-Adapt-Mitig- | | |

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| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Provide funding and support to retain or convert these sites from inappropriate land uses, using management agreements. Establish community reserves. Consider engaging in payment for ecosystem services (PESs) programmes, including REDD+ initiatives (see page 76), as a means of securing financing and local support for activities that will require concerted, landscape level participation. | 45 - 45 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Greater Yellowstone Co-ordinating Committee Three federal agencies are represented on Greater Yellowstone Co-ordinating Committee (GYCC, http://fedgycc.org/), responsible for nearly 53,000 km2 of protected and managed land, including Yellowstone National Park. The GYCC has developed a range of climate change mitigation strategies and practices to be implemented by its state and federal members, and a wide range of adaptation strategies, mainly focused on large wildlife and ecosystem function. Cooperative agreements have led to co-management of very large areas of land, ensuring the sustainability of large, migratory and charismatic species such as American bison and elk. In some states, legal instruments exist which allow landowners to voluntarily cede the right to use their land in certain ways, in exchange for property tax reductions or other forms of recognition. | 45 - 45 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Indigenous peoples: Case of Manú National Park26 Manú National Park in Peru, like many large forested World Heritage sites, is home to resident indigenous communities, who carry out a wide range of subsistence activities within the park including hunting. With new technology come new practices, in this case changing a bow and arrow to a shotgun has taken its toll on game populations. This is mitigated in Manú by a policy that bans firearms inside the site, alongside targeted development activities to encourage people to support conservation. There is, however, evidence that outside interests may pose a threat to the indigenous communities and continuity of their traditional lifestyles. | 46 - 46 | Prot-Adapt-Mitig- | | INDG |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Thinking beyond borders: Case of Monarch Butterfly Biosphere Reserve The Monarch Butterfly Biosphere Reserve in Mexico, where protecting the OUV relates to the migratory phenomenon, requires management interventions not only at the site, but throughout the butterfly's migratory range, which includes Canada and the United States. Although site managers cannot engage with governmental bodies outside their country, they can ensure that appropriate national government agencies are informed of issues that might require international coordination. | 46 - 46 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | GCMs use knowledge of atmospheric physics and historical climates to model temperature and precipitation. Each GCM operates with different assumptions and internal relationships. Because no single GCM is universally correct, most climatologists and other scientists consider it good practice to use several models and express predicted future conditions as the mean of those predictions. However, it is also essential to incorporate variance among the models as a measure of uncertainty.28 GCMs are useful in understanding broad climate patterns and in describing the potential, coarse-scale future conditions to which a site might be exposed. However, they are not useful for predicting the specific conditions that might be experienced by plant, animal or human communities in and around a World Heritage site. Also, our ability to precisely predict future climates is currently limited to a few decades and is better for temperature than precipitation. The lack of precision for precipitation and long-term predictions is a significant limitation in planning management strategies for a site. | 47 - 47 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Set baselines against the outcomes and monitor against these baselines Develop a set of attributes and their indicators to reffect the major site features Identify the features that need to form the basis of the monitoring plan Identify OUV responses to a breach of the thresholds Compare data needed with existing monitoring processes/data and identify gaps Develop a data management system Develop detailed monitoring standards that deffne monitoring purposes, methodologies, etc. to ensure replicability and credibility Agree thresholds including climate-related ones that would trigger concerns Figure 8: Setting up a monitoring plan, adapted from Enhancing our Heritage Toolkit (Hockings et al., 2008). | 60 - 60 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Prior to carrying out the monitoring programme, the management team has reviewed the amount and location of appropriate habitat, and identified a representative number of monitoring sites. It has decided to carry out its work in mid-March, to allow for a build-up of scats and scrapes at the end of the mating season, while preserving tracks in the snow where it has built up between cliff bottoms and slopes, and along ravine edges, favoured snow leopard sites. This means that humans and livestock have yet to be active in the area. On the other hand, some areas will be inaccessible because glacial melt-water has swollen the rivers. | 61 - 61 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | This section has discussed monitoring in terms of the options and actions in relation to climate change adaptation, but of course monitoring is a continuous aspect of protected area management generally and World Heritage site management in particular. Bearing in mind the dynamics of climate change, and the need for constant adjustments, there is no end point. | 62 - 62 | Prot-Adapt-Mitig- | | |

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| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | In order to sustain a site's OUV despite climate change, a manager needs to evaluate both the processes through which management is achieved as well as the specific attributes that contribute to the OUV. Lessons learned will help the team to refine the adaptive strategy, increasing the probability that the OUV will be sustained. | 62 - 62 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | You should not underestimate the demands of time and resources in developing an adaptation strategy, and it might be appropriate to carry out this work while revising or producing your management plan, or in conjunction with the development of wider land management strategies and plans. | 66 - 66 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Expertise in climate change adaptation is growing among the protected area management community, and it is important to keep up to date by reviewing UNESCO World Heritage Centre and IUCN websites, as well as those of international and national NGOs. An increasing number of case studies and examples of strategies is available on the internet, including those referred to here, and they are a valuable source of information. | 66 - 66 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | In conclusion, the following points are worth reiterating: Climate change is a highly complex process, and we cannot predict in detail what future climate conditions might be. However, we can develop some consensus on likely scenarios based on observation, knowledge and expertise, and professional intuition. What is clear is that change is on the way.<br>69 Conclusion 4 The focus of natural World Heritage management is the protection of its Outstanding Universal Value (OUV). | 66 - 67 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Implementing and Executing Entities Eligible Parties who seek financial resources from the Adaptation Fund shall submit proposals directly through their nominated National Implementing Entity (NIE). They may, if they so wish, use the services of Multilateral Implementing Entities (MIE). The implementing entities shall obtain an endorsement from the government. | 74 - 74 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | The European Commission has approved funding for 183 new projects under the fourth call for the LIFE+ programme (2007-2013). The projects are from across the EU and cover actions in the fields of nature conservation, environmental policy, and information and communication. Overall, they represent a total investment of €530 million, of which the EU will provide €244million. | 77 - 77 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | In response to these challenges, the Government of Tunisia has, over several years, installed water-flow control structures at the outflow point of the wetland. The structures help to keep out excess salt water during droughts, while letting water out during particularly wet periods. Upstream, management agreements between various user groups have been developed, ensuring a minimum water flow to the park during critical times. Together, these measures have helped Ichkeul National Park to improve its resilience to drought and sea level rise. | 81 - 81 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | The government embarked on an ambitious infrastructure programme that included an 18 km pipeline, local water retention and management infrastructure and a river diversion scheme. | 81 - 81 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | This site is surrounded by subsistence-level communities, who work the land and gather forest products to make their living. Conditions can be difficult, and food security Water management infrastructure, Keoladeo National Park (India). | 81 - 81 | Prot-Adapt-Mitig- | | |
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | The intimate link between the World Heritage site and the project area was used to raise the interest of potential buyers of carbon credits on the voluntary market. There are more sellers of carbon credits than there are buyers. Under these circumstances, using the connection to nearby World Heritage sites, and demonstrating how a REDD+ project will support World Heritage site adaptation to climate change, may help to attract potential carbon credit buyers. | 82 - 82 | Prot-Adapt-Mitig- | | |

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|---|---|---|---|---|---|
| Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Designing for resilience: Area de Conservación Guanacaste (Costa Rica) and Manú National Park (Peru) Perhaps the best approach to ensuring climate change adaptation is to create protected areas that, by their very design, offer greater resilience to any stresses. Some World Heritage sites enjoy a 'built-in' resilience thanks to their overall design from the outset. They are large, and cover wide climatic gradients, connecting lowlands to highlands, dry areas to wet areas. As temperature and moisture gradients shift over the years, the values of these sites should be better able to adapt to such shifts. One additional supporting strategy is having a site embedded into a larger protected landscape.<br>86 6 Appendices The Area de Conservación Guanacaste in Costa Rica (inscribed 1999, extension 2004) extends from sea level on the Pacific Ocean, over coastal hills and into interior valleys, before rising to the cool mountain tops inland at 1,500 m altitude. | 82 - 83 | Prot-Adapt-Mitig- | | |
| Climate Change and World Heritage - UNESCO 2007 | The World Heritage Committee has recognized this emerging threat and responded at its 29th session by launching an initiative to assess the impacts of climate change impacts on World Heritage and define appropriate management responses. Accordingly, a meeting of experts was held in March 2006 in order to prepare a Report and a Strategy to assist States Parties in addressing this threat, and these documents were endorsed by the Committee at its 30th session in July 2006. | 4 - 4 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | Protecting and managing World Heritage sites in a sustainable and effective manner is a shared responsibility under the Convention. Therefore, there is a need to publicize all available information on the threats posed by climate change and the potential measures for dealing with them. This pub�lication in the World Heritage Papers Series, comprising the report on 'Predicting and managing the effects of climate change on World Heritage' and a 'Strategy to assist States Parties to implement appropriate management responses' is part of that overall effort. | 4 - 4 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | This Convention provides for countries to cooperate in preparing for adaptation to the impacts of climate change; develop and elaborate appropriate and integrated plans for coastal zone manage�ment, water resources and agriculture, and for the protection and rehabilitation of areas, particu�larly in Africa, affected by drought and desertification, as well as floods. | 6 - 6 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | Parties to the UNFCCC are: developing and submitting national reports containing inventories of greenhouse gas emissions by source and removals by sinks using agreed guidelines, adopting national programmes for mitigating climate change, developing strategies for adapting to its impacts, promoting technology transfer and the sustainable management of resources, enhancing greenhouse gas sinks and reservoirs (such as forests). In addition, the countries are taking climate change into account in their relevant social, economic, and environmental policies and cooperating in scientific, technical, and educational matters, as well as public awareness. | 6 - 6 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | In order to respond to the needs for assessing the impacts, vulnerability and adaptation, the UNFCCC secretariat has created a compendium on methods and tools to evaluate adaptation options and web pages to facilitate access to information on methods to evaluate adaptation options. It has conducted expert meetings and workshops with the participation of intergovernmental organizations, United Nations organizations and the community of users to identify opportunities for cooperation. | 7 - 7 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | In 2006, the secretariat produced a technical paper on the application of environmentally sound tech�nologies for adaptation to climate change. This paper contains an overview of: the current knowl�edge and understanding of adaptation to climate change, a framework for assessing technologies for adaptation to climate change, the process of technology development and transfer as relevant to adaptation to climate change, examples of important technologies for adaptation in five sectors (coastal zones, water resources, agriculture, public health, and infrastructure), together with three case studies for each sector, and a synthesis of findings that have implications for climate policy. The paper argues that many technologies exist to adapt to natural weather-related hazards and that these technologies can also play an important part in reducing vulnerability to climate change. Hard and soft technologies are available to develop information and raise awareness, to plan and design adaptation strategies, to implement adaptation strategies, and to monitor and evaluate their per�formance. The paper provides examples of technologies that can be employed to accomplish them. | 7 - 7 | Prot-Adapt-Mitig-Impact | | |

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| Climate Change and World Heritage - UNESCO 2007 | PM_ClimateChange_22 UK 2/05/07 11:55 Page 6<br>7 Realizing the need to obtain adequate funding for adaptation, COP 7 agreed to establish three new funds. The Special Climate Change Fund under the UNFCCC is to support, inter alia, the implemen�tation of adaptation activities where sufficient information is available, and the Least Developed Countries (LDCs) Fund should support, inter alia, the preparation and implementation of national adaptation programmes of action (NAPAs), which will communicate priority activities addressing the urgent and immediate needs and concerns of the LDCs, relating to adaptation to the adverse effects of climate change. A third fund, the Adaptation Fund, was established under the Kyoto Protocol. Only the Adaptation Fund is yet to become operational. | 7 - 8 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | The climate change process has also adopted the Nairobi Work Programme (NWP), the objective of which is to assist all Parties, in particular developing countries, including LDCs and SIDS, to improve their understanding and assessment of impacts, vulnerability and adaptation, and to make informed decisions on practical adaptation actions. It is also expected that the outcomes of this programme will include enhanced capacity at all levels to select and implement high priority adaptation actions; improved information and advice to the COP; enhanced cooperation among Parties, relevant organ�izations, business, civil society and decision makers; enhanced dissemination of information; and enhanced integration of adaptation with sustainable development. The focus areas of the NWP include: data and observations, methods and tools, climate modelling and downscaling, climate�related risks and extreme events, socio-economic information, adaptation planning and practices, technologies for adaptation research, and economic diversification. | 8 - 8 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | The World Heritage Committee could take advantage of the information and products that have been developed by other organizations through the climate change process. Many international organizations are undertaking considerable work on climate change impacts, vulnerability and adaptation, although not all of it is focused on decisions of the COP. | 8 - 8 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | The impacts of climate change on biodiversity are of major concern to the Convention on Biological Diversity (CBD). At its fifth meeting in 2000, the Conference of the Parties drew attention to the seri�ous impacts of loss of biodiversity on terrestrial and marine ecosystems, and on people's livelihoods and requested the Convention's Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) to establish an ad hoc technical expert group which, between 2001 and 2003 carried out an in-depth assessment of the inter-linkages between biodiversity and climate change and its impli�cations for the implementation of the United Nations Framework Convention on Climate Change and its Kyoto Protocol. One of the report's main findings is that there are significant opportunities for mitigating climate change, and for adapting to climate change while enhancing the conservation of biodiversity. The report also identifies a suite of tools, including the ecosystem approach of the Convention, that can help decision makers to assess the likely impacts and make informed choices when designing and implementing mitigation and adaptation projects. | 9 - 9 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | Statement by Ahmed Djoghlaf, Executive Secretary, Convention on Biological Diversity, delivered to the World Heritage and Climate Change Expert Meeting held at UNESCO, Paris, on 16 and 17 of March 2006 PM_ClimateChange_22 UK 2/05/07 11:55 Page 8<br>9 At its seventh meeting in 2004, the Conference of the Parties to the CBD further requested SBSTTA to develop advice for promoting synergy among activities to address climate change at the national, regional and international level, including activities to combat desertification and land degradation, and activities for the conservation of and sustainable use of biodiversity. Another expert group on biodiversity and adaptation to climate change was then established which undertook a detailed assessment on the integration of biodiversity considerations in the implementation of adaptation activities to climate change. SBSTTA welcomed the report at its eleventh meeting late last year, and requested the expert group to further refine its contents. One of the main findings of the report is that the ability of natural and managed ecosystems to adapt autonomously to climate change is insufficient to arrest the rate of biodiversity loss and that directed adaptation towards increasing ecosystem resilience be promoted. | 9 - 10 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | Collectively, the findings of these two reports provide comprehensive advice and guidance on how to mainstream biodiversity into climate change activities, at the biophysical level and at the level of tools and practical approaches. This information can be applied to the management of protected areas in general, and to World Heritage sites in particular, in order to mitigate and adapt to climate change. The Secretariat of the Convention on Biological Diversity is fully committed to exploring ways and means to enhance its collaboration with the World Heritage Committee on this topic, bearing in mind the challenge we all face to reduce significantly by 2010 the rate of biodiversity loss in the world as a contribution to poverty alleviation and to the benefit of all life on earth. | 10 - 10 | Prot-Adapt-Mitig-Impact | | |

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| Climate Change and World Heritage - UNESCO 2007 | World Heritage cultural sites are also exposed to this threat. Ancient buildings were designed for a specific local climate. The migration of pests can have adverse impacts on the conservation of built heritage. Increasing sea level threatens many coastal sites. And the conditions for conservation of archaeological evidence may be degraded in the context of increasing soil temperature. But aside from these physical threats, climate change will impact on social and cultural aspects, with commu�nities changing the way they live, work, worship and socialize in buildings, sites and landscapes, possibly migrating and abandoning their built heritage. | 11 - 11 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | Several actions can be contemplated in the short term to prevent the impacts of climate change on World Heritage properties, define appropriate adaptation measures, and enhance the sharing of knowledge among stakeholders. Such initiatives should be conducted in close collaboration with relevant bodies already involved in climate change and/or heritage and conservation issues, such as the United Nations Framework Convention on Climate Change (UNFCCC), the Intergovernmental Panel on Climate Change (IPCC), the Convention on Biological Diversity (CBD), the UNESCO Man and the Biosphere programme, the Ramsar Convention on Wetlands and the UNESCO conventions deal�ing with cultural heritage. | 12 - 12 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | The management plans of all sites potentially threatened by climate change should be updated to ensure sustainable conservation of their OUV in this context. The impacts of climate change on World Heritage properties must be assessed through appropriate monitoring and vulnerability assessment processes. Potential mitigation measures at the level of the sites and within the World Heritage network should also be investigated, although mitigation at the global and States Parties level is the mandate of the UNFCCC and its Kyoto Protocol. The importance of climate change threats also justifies the need to implement appropriately tailored risk-preparedness measures. As far as remedial measures are concerned, lessons learnt at several sites worldwide show the relevance of designing and implementing appropriate adaptations measures. The effectiveness of several actions has been demonstrated at a number of sites in the past, such as: increasing the resilience of a site by reducing non-climatic sources of stress, preventively draining a glacial lake to avoid the occur�rence of an outburst flood, improving dykes to prevent coastal flooding and supporting traditional methods to protect a site from sand encroachment. | 12 - 12 | Prot-Adapt-Mitig-Impact | | INDG |
| Climate Change and World Heritage - UNESCO 2007 | Strategy to assist States Parties to implement appropriate management responses Preamble: Objectives and requirements Preventive actions Corrective actions: Management, adaptation, and risk management Collaboration, cooperation, and sharing best practices and knowledge Legal issues Conclusion and steps ahead Appendices Expert Meeting of the World Heritage Convention on the Impacts of Climate Change on World Heritage Decision 29 COM 7B.a of the World Heritage Committee, 29th session (2005) Decision 30 COM 7.1 of the World Heritage Committee, 30th session (2006) 4 2 3 PM_ClimateChange_22 UK 2/05/07 11:55 Page 13<br>PM_ClimateChange_22 UK 2/05/07 11:55 Page 14<br>Background 15 Doñana National Park, Spain © Renato Valterza PM_ClimateChange_22 UK 2/05/07 11:55 Page 15<br>Introduction The scientific community now widely agrees on the fact that human activities are disturbing the fragile climatic equilibrium of our planet. The resulting climate change is defined by the United Nations Framework Convention on Climate Change (UNFCCC), in its Article 1, as 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural cli�mate variability observed over comparable time periods'. The UNFCCC thus makes a distinction between 'climate change' attributable to human activities altering the atmospheric composition, and 'climate variability' attributable to natural causes. | 14 - 17 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | BOX 1 Potential climate change impacts on the Doñana National Park (Spain) 1 The Doñana National Park and World Heritage property, in southern Spain, is the largest and most comprehensive conservation area in Iberia and covers an area of 50,000 hectares. | 21 - 21 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | Potential strategies include investing in focussed research and developing a monitoring system, perhaps with the involvement of the public. Conservation planning should also be integrated with climate risk assessment and a coordinated regional effort should be established to analyse information and assess the risk of biodiversity loss. It is also important to increase the topographic diversity and landscape connectivity of protected areas by creating migratory corridors, to reduce or remove other stresses on the ecosystem and to strengthen risk preparedness, in particular for fires. | 22 - 22 | Prot-Adapt-Mitig-Impact | | |

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|---|---|---|---|---|---|
| Climate Change and World Heritage - UNESCO 2007 | The sustainability of this World Heritage site is sensitive to any change in the following climate parameters: sea level rise, sea temperature increase, storm frequency and intensity, precipitation, drought, land run-off, changing oceanic circulation, and ocean acidity. Of central concern are the acute and cumula�tive impacts of coral bleaching, which are triggered when the GBR experiences anomalously high water temperatures. It is important to note, however, that coral bleaching is a major threat to coral reefs every�where. And the threat is not amenable to manage�ment in the short to medium term.6 In 1998 and 2002, major bleaching events occurred in the region. In 2002, between 60 and 95 per cent of corals were affected. Corals of most of the reefs recovered well but a small percentage (less than 5 per cent) of reefs suffered high mortality, losing between 50 and 90 per cent of their corals. As a response, a climate change Response Programme (2004 – 08) was developed to better understand and respond to climate change threats and to prepare an annual Coral Bleaching Response Plan and a climate change Action Plan. The Coral Bleaching Response Plan aims at detecting and measuring bleaching and other short and long term impacts (Satellite imagery, aerial and underwater surveys, community observations) and has received worldwide recognition (and was adapted for the Florida Keys and Indonesia for example). The climate change Action Plan aims at sustaining ecosystems, industries, and communities by identify�ing and implementing relevant management actions, adapting policy and fostering collaborations. | 23 - 23 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | 22 2 Predicting and managing the impacts of climate change on World Heritage 3. Communication of Martin Parry (Co-chair of working group II of the Intergovernmental Panel on Climate Change) at the expert meeting on Climate Change and World Heritage (UNESCO HQ, Paris, 16-17 March, 2006) 4. Communication of Pablo Dourojeani (the Mountain Institute) at the expert meeting on Climate Change and World Heritage (UNESCO HQ, Paris, 16-17 March, 2006) 5. Communication of Greg Terrill (Assistant Secretary, Heritage Division Australian Department of Environment and Heritage) at the expert meeting on Climate Change and World Heritage (UNESCO HQ, Paris, 16-17 March, 2006) 6. Australian Institute of Marine Science Annual Report 2001-2, p 18 PM_ClimateChange_22 UK 2/05/07 11:55 Page 22<br>The GBR management actions are recognized as world's best practice7 and that the GBR has relatively low bleaching to date, but further events will be inevitable. The main challenge is to increase broad resilience, which requires multifactor efforts and in many respects adaptation, continuation and enhancement of current efforts. To increase the broad resilience of the GBR Marine Park, in 2004, the GBRMPA increased the percentage of no-take area within the Marine Park from 5% to 33%. Also, the Australian Government is working closely with the Queensland Government on the Reef Water Quality Protection Plan, which aims to halt and reverse the decline in water quality entering the Marine Park by 2013. | 23 - 24 | Prot-Adapt-Mitig-Impact | | |

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|---|---|---|---|---|---|
| Climate Change and World Heritage - UNESCO 2007 | 24 2 Predicting and managing the impacts of climate change on World Heritage 9. The issues mentioned in this paragraph refer to cultural heritage properties, although, to some extent, it also applies to natural heritage properties. 10. Idem PM_ClimateChange_22 UK 2/05/07 11:55 Page 24 25 Predicting and managing the impacts of climate change on World Heritage 2 Climate indicator Atmospheric moisture change Temperature change Sea-level rises Wind Desertification Climate and pollution acting together Climate and biological effects Physical, social and cultural impacts on cultural heritage - pH changes to buried archaeological evidence - Loss of stratigraphic integrity due to cracking and heaving from changes in sediment moisture - Data loss preserved in waterlogged / anaerobic / anoxic conditions - Eutrophication accelerating microbial decomposition of organics - Physical changes to porous building materials and finishes due to rising damp - Damage due to faulty or inadequate water disposal systems; historic rainwater goods not capable of handling heavy rain and often difficult to access, maintain, and adjust - Crystallisation and dissolution of salts caused by wetting and drying affecting standing structures, archaeology, wall paintings, frescos and other decorated surfaces - Erosion of inorganic and organic materials due to flood waters - Biological attack of organic materials by insects, moulds, fungi, inva�sive species such as termites - Subsoil instability, ground heave and subsidence - Relative humidity cycles/shock causing splitting, cracking, flaking and dusting of materials and surfaces - Corrosion of metals - Other combined effects eg. increase in moisture combined with fertilisers and pesticides - Deterioration of facades due to thermal stress - Freeze-thaw/frost damage - Damage inside brick, stone, ceramics that has got wet and frozen within material before drying - Biochemical deterioration - Changes in 'fitness for purpose' of some structures. For example overheating of the interior of buildings can lead to inappropriate alterations to the historic fabric due to the introduction of engineered solutions - Inappropriate adaptation to allow structures to remain in use - Coastal erosion/loss - Intermittent introduction of large masses of 'strange' water to the site, which may disturb the metastable equilibrium between artefacts and soil - Permanent submersion of low lying areas - Population migration - Disruption of communities - Loss of rituals and breakdown of social interactions - Penetrative moisture into porous cultural heritage materials - Static and dynamic loading of historic or archaeological structures - Structural damage and collapse - Deterioration of surfaces due to erosion - Erosion - Salt weathering - Impact on health of population - Abandonment and collapse - Loss of cultural memory - Stone recession by dissolution of carbonates - Blackening of materials - Corrosion of metals - Influence of bio-colonialisation - Collapse of structural timber and timber finishes - Reduction in availability of native species for repair and maintenance of buildings - Changes in the natural heritage values of cultural heritage sites - Changes in appearance of landscapes - Transformation of communities - Changes the livelihood of traditional settlements - Changes in family structures as sources of livelihoods become more dispersed and distant Climate change risk - Flooding (sea, river) - Intense rainfall - Changes in water-table levels - Changes in soil chemistry - Ground water changes - Changes in humidity cycles - Increase in time of wetness - Sea-salt chlorides - Diurnal, seasonal, extreme events (heat waves, snow loading) - Changes in freeze-thaw and ice storms, and increase in wet frost - Coastal flooding - Sea-water incursion - Wind-driven rain - Wind-transported salt - Wind-driven sand - Winds, gusts and changes in direction - Drought - Heat waves - Fall in water table - pH precipitation - Changes in deposition of pollutants - Proliferation of invasive species - Spread of existing and new species of insects (eg. ter�mites) - Increase in mould growth - Changes to lichen colonies on buildings - Decline | 25 - 27 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | 26 2 Predicting and managing the impacts of climate change on World Heritage Natural Both natural / cultural Cultural 71% 46% 8% Type of sites affected by climate change Coastal and marine sites Glaciers and mountains Terrestrial biodiversity reserves Others 21% 14% 16% 28% Type of biomes for natural World Heritage sites Glacial retreat and melting Sea level rise Loss of biodiversity Species migration Rainfall pattern change and drought Wildffre frequency Coral bleaching Coastal erosion Other 20% 17% 19% 11% 9% 6% 12% Threats of climate change reported for natural World Heritage properties 4% 3% Hurricane and storm frequency Sea level rise Erosion Floods Rainfall pattern change Outdoor painting damage Droughts Other 9% 8% 11% 4% 4% 3% 7% Threats of climate change reported for cultural World Heritage properties 4% PM_ClimateChange_22 UK 2/05/07 11:55 Page 26<br>Implications for the World Heritage Convention11 Introduction The World Heritage Convention is a unique multilateral environmental agreement as it recognizes that parts of the cultural and natural heritage are of outstanding universal value and therefore need to be preserved as part of the heritage of humankind. The key test for inclusion of cul�tural and natural properties on the World Heritage List is that of meeting the criteria of outstanding universal value (OUV), which are assessed through a rigorous evaluation process by the Advisory Bodies of the World Heritage Convention. Once the properties are inscribed on the World Heritage List they benefit from the World Heritage Convention as an important tool for international cooper�ation; however their conservation and management is the primary responsibility of the State Party where the property is located (Article 4). | 27 - 28 | Prot-Adapt-Mitig-Impact | | |

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|---|---|---|---|---|---|
| Climate Change and World Heritage - UNESCO 2007 | Ongoing climate change threats on World Heritage  The present and potential future impacts of climate  change on biodiversity and ecosystems are well studied  and documented. Many of the impacts of climate change  mentioned in section 2.1.1 are already being observed, or  are expected to occur in the short to medium term, in a  number of natural World Heritage sites12. Climate change  could amplify and accelerate major existing management problems and threats affecting the integrity of these prop�erties: species and habitat change, resource extraction,  inefficient site management, invasive species and, in some  cases, armed conflicts. In addition a number of natural  World Heritage properties show already high natural  sensitivity and low capacity to cope with these social and  environmental impacts; which increasingly require the use  of innovative adaptive management mechanisms. | 28 - 28 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | PM_ClimateChange_22 UK 2/05/07 11:55 Page 27<br>Implementing appropriate management strategies  At the same time, extreme weather events, physical and bio�logical changes and increasing pressures from other human  activities affect the conditions of integrity of the properties,  thus requiring appropriate adaptation and mitigation man�agement. Therefore, should this new management require�ment be considered a prerequisite for a site to meet the  conditions of integrity? The integrity required for inscription  of natural World Heritage sites might however prove to be  an asset when it comes to alleviating climate change impacts through 'healthy' landscapes and seascapes. | 28 - 29 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | The Subsidiary Body for Scientific and Technological  Advice (SBSTA) was requested to develop a structured  five-year programme of work on impacts, vulnerability  and adaptation. The draft list of activities (2006-2008)  include methods and tools, data and observations, cli�mate modelling and downscaling, thresholds, socio-eco�nomic data, adaptation practices, research, adaptation  platform and economic diversification. | 29 - 29 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | The UNESCO MAB Programme has therefore, together  with the Mountain Research Initiative (MRI), launched a  project on Global Change in Mountain Regions  (GLOCHAMORE) which will attempt to address global  change issues by reviewing the state of global change  research in selected mountain biosphere reserves. These  will then be used as pilot study areas for implementing  activities that will help in assessing the impacts of global  change on mountain environments and people. The bios�phere reserves selected to take part in the initial stages of  the project include a number of World Heritage sites.14  Therefore, the World Heritage Convention and the  UNESCO MAB Programme could cooperate and coor�dinate their activities in the field of developing and  implementing monitoring, adaptation and mitigation  options for World Heritage sites and Biosphere Reserves  in mountain ecosystems. | 30 - 30 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | Ramsar Convention on Wetlands (1971)  The attention to climate change issues is growing in the  framework of the Ramsar Convention15 leading to the Conference of the Parties (COP8, Valencia 2002) and the  documents prepared for this including 'Climate Change  and Wetlands: Impacts, Adaptation and Mitigation.16  There are plans to update and to look specifically into addi�tional sources of information on wetland ecosystems and  species including inland and coastal wetlands as well as  peatlands. Resolution VIII.3 which was adopted by the  contracting parties states '… that climate change is occurring and may substantially affect the ecological  character of wetlands and their sustainable use' and '... | 30 - 30 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | The management challenges include addressing the  impacts of multiple pressures where climate change is an  added pressure. Wetlands are vulnerable to climate  change and have limited adaptive capacity. Therefore  innovative solutions are required. Management plans need  to consider impacts from climate change and other pres�sures, have to minimize changes in hydrology from other  human activities, to reduce non-climate pressures, to mon�itor the changes. Monitoring is essential to look at the  effectiveness of adaptation options and steps to rectify any  adverse effects should be part of the adaptive manage�ment strategy. A key limitation to implementing adapta�tion and mitigation options for wetlands is the lack of  knowledge of wetland hydrology, functioning, their uses  and past and present management. Pilot research projects  at wetland World Heritage sites, which are also Ramsar  sites, could help to fill this gap. | 30 - 30 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | Contracting Parties to the Ramsar Convention have to  manage wetlands to increase their resilience to climate  change and variability (extreme climatic events - floods  and droughts) and promote wetland and watershed  protection and restoration. The Ramsar Convention rec�ognizes that climate change impacts will vary between  different wetland types and overall adaptation options  are required. Again, the capacity of different regions to  adapt to climate change depends upon their current and  future states of socio-economic development and their  exposure to climate stresses. In general, the potential for  adaptation is more limited for developing countries,  which are also projected to be more adversely affected  by climate change. | 30 - 30 | Prot-Adapt-Mitig-Impact | | |

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|---|---|---|---|---|---|
| Climate Change and World Heritage - UNESCO 2007 | PM_ClimateChange_22 UK 2/05/07 11:55 Page 29<br>30 2 Predicting and managing the impacts of climate change on World Heritage Convention on Biological Diversity (CBD) This Convention covers a wide range of issues related to the conservation and sustainable use of biodiversity. The impacts of climate change on biodiversity are already a major concern to the Convention on Biological Diversity. In 2000, the Conference of the Parties (COP) drew attention to the serious impacts of loss of biodiversity on terrestrial and marine ecosystems, and on people's livelihoods and requested the Convention's Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) to establish an ad hoc technical expert group. This group carried out an in-depth assessment of the inter-linkages between bio�diversity and climate change. There are significant oppor�tunities for mitigating climate change, and for adapting to climate change while enhancing the conservation of bio�diversity. The report also identified tools to help decision makers to assess impacts and make informed choices for mitigation and adaptation projects. | 30 - 31 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | Another expert group on biodiversity and adaptation to climate change was established, which undertook a detailed assessment. One of the main findings is that the ability of natural and managed ecosystems to adapt autonomously to climate change is insufficient to halt the rate of biodiversity loss and that adaptation towards increasing ecosystem resilience should be promoted. If one considers the example of species shifting ranges, although past changes in the global climate resulted in major shifts in species ranges, and biomes, these changes occurred in landscapes that were not as fragmented as today, and with fewer pressures from human activities. Therefore, one of the focus of the CBD includes the creation of corri�dors to protect biodiversity from the effects of climate change, and further, to recognize the important role that protected areas can play in mitigating some of the impacts of climate change. | 31 - 31 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | Networking 'Natural and social systems of different regions have varied characteristics, resources and institutions, and are subject to varied pressures that give rise to differences in sensitivity and adaptive capacity' (Intergovernmental Panel on Climate Change Technical Summary, p.44) This quotation indicates clearly the global impact of climate change. However the challenges need to be addressed at a regional level, with responsibility for adaptation being taken locally. | 32 - 32 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | The schematic below (Figure 1) illustrates the links between impacts, challenges and responses. It suggests that local managers will need to explore the potential for developing or adapting existing management plans and actions to respond to the climate change challenges. | 32 - 32 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | The environmental effects on cultural heritage such as climate change are transboundary. At the very least, regional networks need to be strengthened and focussed on climate change adaptation. UNESCO Regional Offices should encourage and support local initiatives, such as community awareness, emergency preparedness and maintenance training and considering to initiate partner�ships with research-led universities and institutions to ensure that research addresses the climate change prob�lems that cultural heritage is expected Research There is a need for more research on the effects of cli�mate change on both the physical heritage and the social and cultural processes that they are a part of. The Intergovernmental Panel on Climate Change (IPCC), set up in 1988, draws on the work of experts from around the world to provide objective information on climate change for policymakers. Their Assessment Reports provide the technical, scientific and socio-economic information on climate change, possible impacts and responses. Each report includes a Summary for Policy makers. The third Assessment Report was produced in 2001 and the fourth will be published in 2007. | 32 - 32 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | Working Group II of the IPCC is charged with assessing the impact, adaptation and vulnerability of societies to climate change. The report focuses on the effect of climate change on sectors, for example ecosystems, society and settlement and the effects regionally, usually on a continental scale. | 32 - 32 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | Information management, communication, and building public and political support Strengthening of capacity building is important for dealing with effects of climate change as well as for good com�munication and awareness programmes. There is a need to ensure better gathering and analysis of information to identify changing conditions related to climate change. | 33 - 33 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | The notion that all cultural heritage can be saved when confronting climate change must be tackled through information on the meaning and fragility of cultural heritage including adaptation, loss and the notion of abandonment in the face of extreme weather. | 33 - 33 | Prot-Adapt-Mitig-Impact | INTANBILE | |

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| Climate Change and World Heritage - UNESCO 2007 | Communication and building public and political support Mobilizing public and political support for climate change adaptation and mitigation inside and outside World Heritage sites is essential. This has to range from local to regional and global approaches and involve a variety of measures: workshops, exhibitions and expositions, media campaigns, audio-visual material and popular publications which link the global phenomenon of climate change to the local and regional context. Most likely, maximum sup�port is further gained through linking local and regional impacts to individual actions and vice versa. For example, simple and straight-forward ways of communicating the impacts and implications of climate change in a local and regional context raised considerable public and political awareness in the Cape Floral Region in South Africa (see Box 2 on p.19) – with subsequent benefits for research, decision-making, planning and management.19 One of the requests of the Committee in its Decision 29 COM 7B.a related to the use of the World Heritage network is 'to demonstrate management actions that need to be taken to meet [climate change] threats both within the properties and in their wider context'. To address this aspect of the Decision, it is proposed that spe�cific World Heritage sites be used as demonstration mod�els for countries and other stakeholders to design adaptation and mitigation strategies for World Heritage sites facing climate change challenges. Communication on this issue could occur at two levels. First, at the local and regional level where World Heritage sites are used as anchors to build site-based and national awareness and strategies (bringing together NGO's, academics, and other field-based researchers). At the second, global level, the newly developed strategies are disseminated to the World Heritage Committee, States Parties and other stakeholders through NGO networks (Advisory Bodies and other con�servation NGOs), academic networks and UN bodies. | 33 - 33 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | Local communities should be closely involved in the processes of investigation of the impacts of climate change and the development of adaptation strategies. The strong links between cultural and natural heritage could also be reflected in these case studies. These case studies should also be the opportunity to illustrate how adaptation meas�ures could be developed to avoid the general feeling of dis�couragement of the public in the face of climate change. | 34 - 34 | Prot-Adapt-Mitig-Impact | | INDG |
| Climate Change and World Heritage - UNESCO 2007 | PM_ClimateChange_22 UK 2/05/07 11:55 Page 33<br>34 2 Predicting and managing the impacts of climate change on World Heritage A two-pronged approach is required: first, the vulnerabil�ity of natural World Heritage sites, which are particularly at risk, should be assessed by the States Parties and specific site-level mitigation and adaptation strategies should be designed and implemented in partnership with relevant stakeholders. Second, States Parties and site managers need to look beyond the individual site level and develop and implement regional and/or transboundary mitigation and adaptation strategies that reduce the vulnerability of natural World Heritage sites in a larger landscape or seascape context. Natural World Heritage sites must be seen as core sites within functioning regional networks of protected areas, conservation corridors and stepping stones. 'Healthy' World Heritage sites can contribute con�siderably to 'healthy' landscapes and seascapes that are better able to buffer climate change impacts. The World Heritage Centre and Advisory Bodies to the World Heritage Convention should encourage States Parties and site managers, in collaboration with relevant academic and research institutions, to accomplish these tasks and make available their knowledge and experience in the field of climate change adaptation and mitigation. | 34 - 35 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | Assess future climate change scenarios through appropriate tools and guidelines A comprehensive set of technical guidelines to assess cli�mate change impacts and response strategies in general is available from the Intergovernmental Panel on Climate Change,24,25 and has been reviewed from a coastal per�spective.26 Climate change impacts and response strate�gies have been recently discussed in detail for islands.27 22. For a detailed discussion see Schröter et al. (2005, Assessing vul�nerabilities to the effects of global change: an eight step approach. Mitigation and Adaptation Strategies for Global Change 10, 573-596). According to them, for vulnerability assessments, the role of numerical modelling is the projection of future states of a system. Here, steps 1-3 take place prior to modelling, whereas steps 4-8 take place as part of the modelling and modelling refinement process. | 35 - 35 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | Risk and vulnerability maps No one can afford to wait for all the research to be com�pleted for guidance on the management of cultural her�itage under climate change conditions. It will be important to produce risk and vulnerability maps of World Heritage regions and sub-regions which overlay climate data and heritage site locations so that an overview of the risks to different aspects of cultural heritage can be obtained. Using this information, detailed adaptation strategies can then be developed. | 36 - 36 | Prot-Adapt-Mitig-Impact | | |

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| Climate Change and World Heritage - UNESCO 2007 | Applying adaptive management responses  In many areas, promising management responses are  being developed and implemented already. A number of  different solutions to specific problems posed by climate  change are available. Technical solutions are available in  some cases, but they might not be affordable or feasible  in all cases, and they might also be controversial when it  comes to application to World Heritage sites, with poten�tial impacts on the conditions of integrity. For example, in  some coastal areas, reinforcing dykes and drains to deal  with rising sea level have been considered as options,  whereas in other coastal areas, management has  favoured a planned retreat of settlements from low-lying  areas. The water level of some wetlands can be con�trolled by regulating water inflow or outflow with dams,  but increasing temperatures and decreasing precipitation  will in many areas result in stiffer competition between  nature and people for water. | 37 - 37 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | BOX 10  Reducing the risk of GLOF in the Sagarmatha  National Park (Nepal)33  The Tsho Rolpa glacial lake project is one of the most  significant examples of collaborative anticipatory plan�ning by the government, donors, and experts in GLOF  mitigation. Tsho Rolpa was estimated to store approxi�mately 90-100 million m3, a hazard that called for  urgent attention. A 150-meter tall moraine dam held  the lake, which if breached, could cause a GLOF event in which a third or more of the lake could flood down�stream. This threat led to a collaborative action by the  Nepalese Government and the Netherlands  Development Agency, with the technical assistance of  Reynolds Geo-Sciences Ltd., supported by the United  Kingdom Department for International Development. | 37 - 37 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | From this box it is particularly important to stress that  realistic response strategies cannot be planned without  taking into account the impacts from other non-climatic  stresses on natural ecosystems, such as habitat frag�mentation and loss, alien and invasive species, over�exploitation, pollution, sedimentation, etc which  severely impede natural adaptation and mitigation  strategies. Hence, there is a need for the World Heritage  Convention to continue enhancing its work in assessing  the management and conditions of integrity of World  Heritage properties, both through reactive monitoring and periodic reporting. | 38 - 38 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | Monitoring and adaptative management  Monitoring the impact of climate change is obviously an  important issue, as was mentioned in the sections on 'research' and 'information management'. But the care�ful monitoring of adaptive management measures must  also be planned in the context of climate change and  World Heritage. | 38 - 38 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | Monitoring climate, climate impacts and management  responses is critical. Only then will one be able to tell  which responses do work and which do not. But few of  the existing monitoring measures are tailored to issues  relevant to climate change adaptation and mitigation of  37  Predicting and managing the impacts of climate change on World Heritage 2  34. Shafer, 1999. National park and reserve planning to protect bio�logical diversity: some basic elements. Landscape and Urban  Planning 44, 123-153. | 38 - 38 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | PM_ClimateChange_22 UK 2/05/07 11:55 Page 37<br>38  2 Predicting and managing the impacts of climate change on World Heritage  protected areas. Capacity-building, for example in rela�tion to fire and risk management, is underway in many  areas, sometimes already linked to the additional prob�lems posed or accelerated by climate change. In many cases, adaptive management, if implemented properly,  should help to buffer climate change impacts. Adaptive  management is a systematic process of continually  improving policies and practices by learning from the  results of previous actions. | 38 - 39 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | Experience and lessons learned on addressing climate  change impacts stress the need for using a number of  management responses at national and local levels. The  World Heritage Convention provides an opportunity to  develop strategies to implement relevant actions in respect  of cultural and natural heritage properties threatened by  climate change. Given the complexity of this issue, States  Parties may request guidance from the World Heritage  Committee to implement appropriate management  responses to face the threats posed by climate change on  their natural and cultural properties inscribed on the World  Heritage List. | 41 - 41 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | Therefore, the main objective of this strategy is to review  the main topics that should be considered when preparing  to implement preventive and/or corrective management  responses to deal with the adverse impacts of climate  change. | 41 - 41 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | Conservation is the management of change, and climate  change is one of the most significant global challenges  facing society and the environment today. The actions that  need to be taken to safeguard heritage are threefold:   a. Preventive actions: monitoring, reporting and mitiga�tion of climate change effects through environmentally  sound choices and decisions at a range of levels: indi�vidual, community, institutional and corporate. | 41 - 41 | Prot-Adapt-Mitig-Impact | | |

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| Climate Change and World Heritage - UNESCO 2007 | Lastly, climate change is one risk among a number of chal�lenges facing World Heritage sites. This threat should be considered in the broader context of the conservation of these sites. | 41 - 41 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | Mitigation** The UNFCCC is the UN instrument through which mitiga�tion strategies at the global and States Parties level is being addressed. However, the World Heritage community could participate in climate change mitigation at the level of the World Heritage through: a. Global level actions (World Heritage Convention): i. Provide information to IPCC and UNFCCC on the impacts of climate change on World Heritage sites to assist them in tailoring mitigation strategies. | 41 - 41 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | Corrective actions: Management, adapta�tion, and risk management* The States Parties need to be aware of the risks posed by climate change and that clear short term actions are needed and possible: a. Global level actions (World Heritage Convention): i. Include climate change as an additional source of stress in the Strategy for reducing risks from disasters at World Heritage properties which is presented as a separate working Document (WHC-06/30.COM/7.2), including approaches to vulnerability assessment. | 42 - 42 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | ii. Request new and existing sites to integrate climate change issues into new and revised management plans (as appropriate) including: risk preparedness, adaptive design and management planning. | 42 - 42 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | PM_ClimateChange_22 UK 2/05/07 11:55 Page 41<br>42 3 Strategy to assist States Parties to implement appropriate management responses iv. Develop communication strategies taking advantage of the World Heritage global network to inform the public and policy makers about the impacts of cli�mate change on World Heritage sites and build pub�lic and political support for actions to address the situation. | 42 - 43 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | ii. Ensure that training courses on risk assessments, reporting, adaptation and monitoring are coordi�nated with other international institutions, Advisory Bodies, and secretariats of other conventions. | 43 - 43 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | c. State Party / site level actions: i. Provide information to decision-makers, stakehold�ers, local communities, users of the sites, site man�agers, and other heritage specialists about the impacts of climate change on sites, management responses, possible assistance, existing networks, specific training, courses, and long- distance learn�ing opportunities. | 43 - 43 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | Legal issues After having considered the range of actions to be under�taken in the framework of the management of climate change impacts on World Heritage, the group of experts considered that when the Operational Guidelines are next revised, the possibility of including climate change related aspects could be explored. | 43 - 43 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | While opportunities are being explored with donors for implementing pilot projects on vulnerability assessment and adaptation at some World Heritage sites, the impacts of climate change can be effectively addressed only when the strategy outlined in this publication is applied at the field level. It is for this purpose that the World Heritage Committee has requested States Parties and all partners concerned to implement this strategy to protect the out�standing universal values, integrity and authenticity of World Heritage sites from the adverse effects of climate change, to the extent possible and within the available resources. | 45 - 45 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | 4 Conclusion and steps ahead 44 PM_ClimateChange_22 UK 2/05/07 11:55 Page 44<br>45 Chinguetti mosque, Mauritania © UNESCO / Galy Bernard Appendices PM_ClimateChange_22 UK 2/05/07 11:55 Page 45<br>Expert Meeting of the World Heritage Convention on the Impacts of Climate Change on World Heritage The World Heritage Committee at its 29th session (Durban, 2005) requested the World Heritage Centre (WHC), in collaboration with the Advisory Bodies, inter�ested States Parties and petitioners who had drawn the attention of the Committee to this issue, to convene a broad working group of experts on the impacts of climate change on World Heritage (Decision 29 COM 7B.a). The Committee took this decision noting 'that the impacts of climate change are affecting many and are likely to affect many more World Heritage properties, both natural and cultural in the years to come'. The Committee requested the broad working group of experts to: • review the nature and scale of the risks posed to World Heritage properties arising specifically from climate change; • jointly develop a strategy to assist States Parties to imple�ment appropriate management responses; and • prepare a joint report on 'Predicting and managing the effects of climate change on World Heritage' to be examined by the Committee at its 30th session (Vilnius, 2006). | 45 - 47 | Prot-Adapt-Mitig-Impact | | |

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|---|---|---|---|---|---|
| Climate Change and World Heritage - UNESCO 2007 | The meeting was prepared after a rigorous and extensive consultation process between a core group, comprising the World Heritage Centre, the Advisory Bodies, and experts from the State Party of the United Kingdom. The United Nations Foundation (UNF) provided crucial financial support to the World Heritage Centre to enable some of the preparatory and follow-up actions. The agenda, list of participants and background documents for the expert meeting were prepared through collaboration between the core group. A background document compiled information on the assessment and management of the impacts of climate change in the context of World Heritage. A number of case studies on the impacts of climate change on specific World Heritage sites were also submitted by many experts for consideration by the participants to the meeting. | 47 - 47 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | PM_ClimateChange_22 UK 2/05/07 11:55 Page 46<br>47 Appendices 16 March 2006 09.00 Registration 09.15 – 10.00 Session 1 Opening Session Chair: Mr Francesco Bandarin (Director of the WHC) Rapporteur: Dr Mechtild Rössler (Chief Europe and North America WHC) Welcome Mr Francesco Bandarin (Director of the WHC) Opening remarks Ms Ina Marciulionyte (Chairperson of the WH Committee) Keynote address on 'Implications of climate change Mr Martin Parry for World Heritage sites' (Co-chair of WGII of the IPCC) Overview of the decision of the World Heritage Mr Kishore Rao Committee, the agenda, the objectives of the meeting, (Deputy Director of the WHC) the strategic requirements and report on the results of the climate change survey submitted to States Parties 10.00 – 10.30 Coffee break 10.30 – 13.00 Session 2 Natural Heritage Chair: Mr David Sheppard (Head of IUCN's Programme on Protected Areas) Rapporteur: Mr Guy Debonnet (WHC) 2-5 min Convention on Biological Diversity Statement on behalf of Mr Ahmed Djoghlaf (Executive Secretary of the CBD) 10 min Key issues for climate change and wetlands Dr Habiba Gitay (on behalf of Ramsar Convention) (World Resources Institute) 10 min United Nations Framework Convention Mr Festus Luboyera on Climate Change (UNFCCC Secretariat) 10 min UNESCO Man and the Biosphere Programme Dr Natarajan Ishwaran (UNESCO, Division of Ecological and Earth Sciences) 35 min Case Study 1: 'Towards conservation strategies for Mr Guy Midgley and Mr Bastian Bomhard future climate change in the Cape Floral Region [presenting author] (South African National Protected Areas (South Africa)' Biodiversity Institute) 35 min Case Study 2: The Great Barrier Reef (Australia) Dr Greg Terrill (Australian Department of Environment and Heritage) 35 min Case Study 3: 'Risks, points of view and conflicts Mr Pablo Dourojeani in the Huascarán NP World Heritage site (Peru) due (The Mountain Institute, Peru) to climate change' 13.00 – 14.00 Lunch Break Agenda of the Expert Meeting on Climate Change and World Heritage Special Expert Meeting of the World Heritage Convention: Climate Change and World Heritage UNESCO HQ, Paris (France) 16-17 March, 2006 16 March 2006 ... | 47 - 48 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | PM_ClimateChange_22 UK 2/05/07 11:55 Page 49<br>50 Appendices Decision 29 COM 7B.a of the World Heritage Committee, 29th session (2005) The World Heritage Committee, 1. Having examined Document WHC-05/29.COM/7B.Rev and the draft Decision 29 COM 7B.a.Rev, 2. Recognizing the work being undertaken within the framework of the UN Convention on Climate Change (UNFCC), and the need for a proper coor�dination of such work with the activities under the Convention, 3. Takes note of the four petitions seeking to have Sagarmatha National Park (Nepal), Huascaran National Park (Peru), the Great Barrier Reef (Australia) and the Belize Barrier Reef Reserve System (Belize) included on the List of World Heritage in Danger, 4. Appreciates the genuine concerns raised by the various organizations and individuals supporting these petitions relating to threats to natural World Heritage properties that are or may be the result of climate change, 5. Further notes that the impacts of climate change are affecting many and are likely to affect many more World Heritage properties, both natural and cultural in the years to come, 6. Encourages all States Parties to seriously consider the potential impacts of climate change within their management planning, in particular with monitoring, and risk preparedness strategies, and to take early action in response to these potential impacts; 7. Requests the World Heritage Centre, in collabora�tion with the Advisory Bodies, interested States Parties and petitioners, to establish a broad work�ing group of experts to: a) review the nature and scale of the risks posed to World Heritage proper�ties arising specifically from Climate Change; and b) jointly develop a strategy to assist States Parties to implement appropriate management responses, 8. Welcomes the offer by the State Party of the United Kingdom to host a meeting of such work�ing group of experts, 9. Requests that the working group of experts, in consultation with the World Heritage Centre, the Advisory Bodies and other relevant UN bodies, prepare a joint report on 'Predicting and managing the effects of climate change on World Heritage', to be examined by the Committee at its 30th session (2006), 10. Strongly encourages States Parties and the Advisory Bodies to use the network of World Heritage properties to highlight the threats posed by climate change to natural and cultural heritage, start identifying the properties under most serious threats, and also use the network to demonstrate management actions that need to be taken to meet such threats, both within the properties and in their wider context, 11. Also encourages UNESCO to do its utmost to ensure that the results about climate change affecting World Heritage sites reach the public at large, in order to mobilize political support for activities against climate change and to safeguard in this way the livelihood of the poorest people of our planet. | 50 - 51 | Prot-Adapt-Mitig-Impact | INTANBILE | |

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|---|---|---|---|---|---|
| Climate Change and World Heritage - UNESCO 2007 | Decision 30 COM 7.1 of the World Heritage Committee, 30th session (2006) The World Heritage Committee, 1. Having examined Document WHC-06/30.COM/7.1, 2. Recalling Decision 29 COM 7B.a adopted at its 29th session (Durban, 2005), 3. Also recalling the submission in 2005 of four peti�tions by civil society and non-governmental organ�izations on the impacts of Climate Change on World Heritage properties, complemented by an additional petition in February 2006, 4. Further recalling paragraph 44 of the Operational Guidelines, 5. Thanks the Government of the United Kingdom for having funded the meeting of experts, which took place on the 16th and 17th of March 2006 at UNESCO Headquarters in Paris, and also thanks the United Nations Foundation for its support, as well as all the experts who contributed to the meeting, 6. Endorses the 'Strategy to assist States Parties to implement appropriate management responses' described in Document WHC-06/30.COM/7.1, and requests the Director of the World Heritage Centre to lead the implementation of the 'Global PM_ClimateChange_22 UK 2/05/07 11:55 Page 50<br>51 Appendices level actions' described in the Strategy through extrabudgetary funding and also takes note of the report on 'Predicting and managing the impacts of Climate Change on World Heritage', 7. Encourages UNESCO, including the World Heritage Centre, and the Advisory Bodies to dis�seminate widely this strategy, the report, and any other related publications through appropriate means to the World Heritage community and the broader public, 8. Requests States Parties and all partners concerned to implement this strategy to protect the Outstanding Universal Value, integrity and authen�ticity of World Heritage sites from the adverse effects of Climate Change, to the extent possible and within the available resources, recognizing that there are other international instruments for coordinating the response to this challenge, 9. Invites States Parties, the World Heritage Centre and the Advisory Bodies to build on existing Conventions and programmes listed in Annex 4 of Document WHC-06/30.COM/7.1, in accordance with their mandates and as appropriate, in their implementation of Climate Change related activities, 10. Also requests States Parties, the World Heritage Centre, and the Advisory Bodies to seek ways to integrate, to the extent possible and within the available resources, this strategy into all the rele�vant processes of the World Heritage Convention including: nominations, reactive monitoring, peri�odic reporting, international assistance, capacity building, other training programmes, as well as with the 'Strategy for reducing risks from disasters at World Heritage properties' (WHC-06/30.COM/7.2), 11. Strongly encourages the World Heritage Centre and the Advisory Bodies in collaboration with States Parties and other relevant partners to develop proposals for the implementation of pilot projects at specific World Heritage properties espe�cially in developing countries, with a balance between natural and cultural properties as well as appropriate regional proposals, with the objective of developing best practices for implementing this Strategy including preventive actions, corrective actions and sharing knowledge, and recommends to the international donor community to support the implementation of such pilot projects, 12. Further requests the States Parties and the World Heritage Centre to work with the Intergovernmental Panel on Climate Change (IPCC), with the objective of including a specific chapter on World Heritage in future IPCC assessment reports, 13. Requests the World Heritage Centre to prepare a policy document on the impacts of climate change on World Heritage properties involving consulta�tions with relevant climate change experts and practitioners of heritage conservation and man�agement, appropriate international organizations, and civil society, to be discussed at the General Assembly of States Parties in 2007. A draft of the document should be presented to the | 51 - 52 | Prot-Adapt-Mitig-Impact | | |
| Climate Change and World Heritage - UNESCO 2007 | The fact that climate change poses a threat to the outstanding universal values of World Heritage sites has several implications for the 1972 Convention. Lessons learnt at some sites show the relevance of designing and implementing appropriate adaptations measures. Research at all levels would also have to be promoted in collaboration with the various bodies involved in climate change work, especially for cultural heritage where the level of involvement of the scientific community needs to be enhanced. | 4 - 4 | Prot-Adapt-Mitig- | | |
| Climate Change and World Heritage - UNESCO 2007 | In the area of technology transfer, the UNFCCC secretariat has prepared a number of reports which are directly or partially relevant to adaptation, including technical papers on: coastal adaptation technologies, and enabling environments with specific references to adaptation technologies. | 7 - 7 | Prot-Adapt-Mitig- | | |
| Climate Change and World Heritage - UNESCO 2007 | In addition, the secretariat has established a technology information system (TT:CLEAR) which includes following elements relating to adaptation: inventory of existing adaptation centres; adap�tation technology projects (mainly from national communications of both Annex I and non-Annex I Parties); and an adaptation technologies database. | 7 - 7 | Prot-Adapt-Mitig- | | |
| Climate Change and World Heritage - UNESCO 2007 | The secretariat is facilitating Parties to undertake capacity-building activities related to the needs for vulnerability and adaptation assessment and implementation of adaptation measures in devel�oping countries and countries with economies in transition. Furthermore efforts are underway to develop a web-based information clearing house that would support networking and partnership activities between Parties, intergovernmental organizations and non-governmental organizations, and to promote informal exchanges of information on actions relating to education, training and public awareness. | 7 - 7 | Prot-Adapt-Mitig- | | |

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| Climate Change and World Heritage - UNESCO 2007 | In this scenario, the conservation of World Heritage natural sites may be jeopardized. Increased ocean temperature and acidification pose a threat to marine biodiversity. Many marine World Heritage sites are tropical coral reefs whose exposure to bleaching events is increasing, possibly leading to massive extinction of coral reefs. The increase of atmospheric temperature is also lead�ing to the melting of glaciers worldwide (in both mountainous and Polar Regions). Lastly, terrestrial biodiversity may also be affected with species shifting ranges, changes in the timing of biological cycles, modification of the frequency and intensity of wildfires, migration of pests and invasive species, etc. | 11 - 11 | Prot-Adapt-Mitig- | | |
| Climate Change and World Heritage - UNESCO 2007 | The Intergovernmental Panel on Climate Change (IPCC) states in its Third Assessment Report that 'The Earth's climate system has demonstrably changed on both global and regional scales since the pre�industrial era, with some of these changes attribut�able to human activities'. To limit the amplitude of climate change, mitigation (reducing the emission and enhancing the sinks of greenhouse gases) is needed, but the same report mentions that 'adapta�tion is a necessary strategy at all scales to comple�ment climate change mitigation efforts'. | 17 - 17 | Prot-Adapt-Mitig- | | |
| Climate Change and World Heritage - UNESCO 2007 | And second, because appropriate management responses consist in a 'no regret-policy' since efforts to reduce the vulnerability and increase the resilience of sites to existing non-climatic pressures and threats would also reduce their vulnerability to climate change related stresses. | 17 - 17 | Prot-Adapt-Mitig- | | |
| Climate Change and World Heritage - UNESCO 2007 | The Thames Barrier can go to 2025 before the 1000 year return flood event is exceeded. World Heritage site managers need to engage in the wider planning processes for a new Thames Barrier, in flood management planning for London and in develop�ment and land-use planning. The Management Plans of World Heritage sites should incorporate climate change adaptation in their guiding principles for management over the next 25-30 years and in the quinquennial revision of the management objectives. | 25 - 25 | Prot-Adapt-Mitig- | | |
| Climate Change and World Heritage - UNESCO 2007 | Implications in the context of the World Heritage Convention In the specific context of the World Heritage Convention, climate change raises many concerns that are of critical nature for the future implementation of the World Heritage Convention. Natural World Heritage sites are inscribed on the World Heritage List if they meet one or more of the criteria of outstanding universal value and also meet the conditions of integrity13. At present, if a site is threatened by serious and specific danger – both ascer�tained and/or potential danger – it can be inscribed in the List of World Heritage in Danger (paragraph 180, Operational Guidelines). The World Heritage Convention also notes that if a property loses the characteristics which warranted its inscription on the World Heritage List it can be deleted from the List (paragraph 176(e), Operational Guidelines). Furthermore the States Parties of the World Heritage Convention have the duty of ensuring the pro�tection, conservation and transmission to future genera�tions of the properties located on its territory (Article 4). | 28 - 28 | Prot-Adapt-Mitig- | | |
| Climate Change and World Heritage - UNESCO 2007 | • Should the World Heritage Convention – and its associ�ated Operational Guidelines seriously consider the fact that for some natural properties it will be impossible to maintain the 'original' OUV values for which they were originally inscribed on the World Heritage List, even if effective adaptation and mitigation strategies are applied; therefore requiring an 'evolving' assessment of OUV values? | 28 - 28 | Prot-Adapt-Mitig- | | |
| Climate Change and World Heritage - UNESCO 2007 | The Programme of work (Buenos Aires) requested further implementation of actions including: • data and modelling, vulnerability and adaptation assess�ment and implementation; • that the Global Environment Facility report on support of the programme; • that the UNFCCC secretariat organize regional work�shops to facilitate information exchange and integrated assessments on adaptation reflecting regional priorities. | 29 - 29 | Prot-Adapt-Mitig- | | |
| Climate Change and World Heritage - UNESCO 2007 | In the meantime three new funds have been established, a data base on local coping strategies was made available, capacity-building frameworks have been agreed on, a Consultative Group of Experts (CGE) has developed hands�on training materials and a seminar on the development and transfer of technologies for adaptation took place in June 2005. | 29 - 29 | Prot-Adapt-Mitig- | | |
| Climate Change and World Heritage - UNESCO 2007 | A major component of adaptation that needs further attention is the assessment of the vulnerability of wetlands to climate change. Many wetlands are vulnerable to climate change either due to their sensitivity to changes in hydrological regimes and/or due to the other pressures from human activities. | 30 - 30 | Prot-Adapt-Mitig- | | |
| Climate Change and World Heritage - UNESCO 2007 | In 2004, the 7th COP (Kuala Lumpur, 2004) promoted syn�ergy among the activities to address climate change, including desertification and land degradation, conserva�tion, sustainable use of biodiversity, and the development by 2010 of national-level conservation strategies that are specifically designed to be resilient to climate change. | 31 - 31 | Prot-Adapt-Mitig- | | |

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| Climate Change and World Heritage - UNESCO 2007 | Designing management plans accounting for the issue of climate change If a Management Plan is specifically designed and format�ted to foster its use as a working document which can be updated on a regular basis, then it can become a key tool in the effective stewardship of World Heritage sites under threat from climate change and actions in response to cli�mate change can be flexibly introduced throughout the document. | 31 - 31 | Prot-Adapt-Mitig- | | |
| Climate Change and World Heritage - UNESCO 2007 | The following specific actions to adapt to climate change might be necessary at a regional or local level to ensure a continuous redefinition of adaptation strategies as climate projections are refined: • Enhancement of appropriate education and traditional skills. | 31 - 31 | Prot-Adapt-Mitig- | | |
| Climate Change and World Heritage - UNESCO 2007 | • Training on the various problems and possible responses to climate change in all aspects of conservation activity namely, development of traditional skills, monitoring, management and emergency preparedness. | 31 - 31 | Prot-Adapt-Mitig- | | |
| Climate Change and World Heritage - UNESCO 2007 | Level of actions (site, local, landscape, State Party, regional or thematic, global level) and networking Involvement of local communities A strong focus also needs to be put on local knowledge sys�tems and the way that they understand and adapt to changes in climate. Communities need to be a part of the overall process of understanding and dealing with climate change (e.g. as mentioned in the case studies on the Huascarán National Park, see Box 4 on p.17). Local influen�tial sectors should also be part of this process such as tourism (e.g. in the Great Barrier Reef region, see Box 5 on p.17), or industry (such as mining in the Huascarán National Park, see Box 4 on p.17). This participation would include management planning and implementation, monitoring, and so on. | 31 - 31 | Prot-Adapt-Mitig- | | INDG |
| Climate Change and World Heritage - UNESCO 2007 | Information management Scientific understanding of traditional materials and assemblies is the foundation of sustainable management of World Heritage sites in a changing climate (including rain penetration, high summer temperatures and chloride loading). Information based on cross-field monitoring need to be sensitive to the scale and time of problems and guidance must be designed accordingly. | 33 - 33 | Prot-Adapt-Mitig- | | |
| Climate Change and World Heritage - UNESCO 2007 | Subsequently, these case studies could be used as field experimental pilot sites for the development of appropri�ate strategies. From these examples a number of key prin�ciples can be derived on which sustainable adaptive responses to climate change can be developed. These principles are: • To ensure that the development of education and the teaching of traditional skills is adapted to the needs of a changing environment; • To undertake rigorous ongoing scientific monitoring of changes in condition of cultural heritage materials; • To recognize that maintenance measures will be tested more severely due to climate change and may require a greater proportion of available resources; • To design flexible management planning objectives to enable priorities to be re-evaluated in response to climate change; • To carry out scientific research to develop understand and knowledge of historic and archaeological materials to support local/regional decision-making and to place cultural values and significance in their social/environ�mental context. | 34 - 34 | Prot-Adapt-Mitig- | INTANBILE | |
| Climate Change and World Heritage - UNESCO 2007 | Cultural heritage Regional and thematic approach Regional strategies provide a link between global climate change initiatives and local management plans since cli�mate change data is based on regional scenarios. It is therefore appropriate to build on relevant available infor�mation and to create information of common interest to World Heritage sites in a region. A regional strategy could, for example, interpret IPCC data to make them rel�evant to the local situation; it could promote the creation of vulnerability maps for the region and sub regions and it could provide guidance on the monitoring programmes that might be appropriate for World Heritage sites in the region which might be affected differently by different climate change parameters. Thematic groupings of sites likely to face similar threats such as archaeological, mov�able, coastal, mountainous or marine sites, could also be developed. | 36 - 36 | Prot-Adapt-Mitig- | | |
| Climate Change and World Heritage - UNESCO 2007 | Local approach The obligation under the World Heritage Convention to develop management systems for World Heritage sites provides an opportunity to integrate climate change adaptation measures in the process. Documents such as management plans should include a statement of the objectives necessary for the long term preservation of the World Heritage sites and its landscape setting, aiming to balance the interests of conservation, public access, and the interests of those who live and work in the area. The objectives could be based on: • Identification of the outstanding values of the World Heritage site including the reasons that make the World Heritage site special and justification for its inscription as a World Heritage site. However, the pro�tection of World Heritage site values and sympathetic land management within the area greatly depends on identifying and resolving key management issues. | 36 - 36 | Prot-Adapt-Mitig- | | |
| Climate Change and World Heritage - UNESCO 2007 | • An assessment of why the World Heritage site is sensi�tive and vulnerable to the pressures of climate change including objectives for the management of the World Heritage site based on a strategic view over 20, 25 or 30 years, and medium-term objectives for 5 to 10 years. | 36 - 36 | Prot-Adapt-Mitig- | | |

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| Climate Change and World Heritage - UNESCO 2007 | • Wireless communication adaptation of wireless proto�cols to building and site sensors such as infestation sur�veying equipment. | 37 - 37 | Prot-Adapt-Mitig- | | |
| Climate Change and World Heritage - UNESCO 2007 | Adaptation  Natural heritage  There is a need to better link World Heritage properties  with corridors and conservation-friendly land/water uses  in the framework of wider landscapes/seascapes plan�ning and management. | 37 - 37 | Prot-Adapt-Mitig- | | |
| Climate Change and World Heritage - UNESCO 2007 | Response strategies that enable protected areas and pro�tected-area networks to adapt to climate change stress  the importance for approaches beyond the individual site  level.31,32 World Heritage sites are largely isolated from  each other, fall in very different biogeographical and  political entities, and do not share common management  systems or structures. Faced with climate change, World  Heritage sites must be considered in the context of the  surrounding matrix of other land uses and protected  areas. In most cases, response strategies for successful  adaptation that do not recognize this need will fail. | 37 - 37 | Prot-Adapt-Mitig- | | |
| Climate Change and World Heritage - UNESCO 2007 | Adaptation to glacier melting in mountainous areas is  limited to reducing the threat posed by Glacial Lake  Outburst Floods (GLOF) events by preventive lake drain�ing as was conducted in the Sagarmatha National Park in  1998-2002 (see Box 10 below). | 37 - 37 | Prot-Adapt-Mitig- | | |
| Climate Change and World Heritage - UNESCO 2007 | Mitigation  Mitigation consists in an anthropogenic intervention to  reduce the sources or enhance the sinks of greenhouse  gases. The UN Framework Convention on Climate  Change is the preferred international tool to address  mitigation at the global and States Parties levels. | 38 - 38 | Prot-Adapt-Mitig- | | |
| Climate Change and World Heritage - UNESCO 2007 | However, some mitigation opportunities could be   contemplated in the context of the World Heritage  Convention at the level of the World Heritage sites. | 38 - 38 | Prot-Adapt-Mitig- | | |
| Climate Change and World Heritage - UNESCO 2007 | Second, the World Heritage Centre oversees a number  of conservation projects aiming at restoring degraded  habitats in natural World Heritage sites. Such activities  indirectly contribute to the improvement of carbon  sequestration and this could be quantified in more  details. | 38 - 38 | Prot-Adapt-Mitig- | | |
| Climate Change and World Heritage - UNESCO 2007 | To keep a realistic perspective, we must be aware that the  total carbon dioxide sequestrated in World Heritage sites  is probably limited because of the relatively limited area  concerned. The benefit of mitigation at World Heritage  sites is therefore likely to be negligible on a quantitative  basis. Nevertheless, considering the iconic character of  the World Heritage sites and the powerful communica�tion tool of the World Heritage network, it would be  most useful in terms of best practices advertising. | 38 - 38 | Prot-Adapt-Mitig- | | |
| Climate Change and World Heritage - UNESCO 2007 | • A range of responses to climate change are defined by  the sites. They may differ between cultural heritage  sites and natural heritage sites. Responses may include  monitoring, maintaining, managing and/or carrying  out further research – all within the framework pro�vided by a site's management system. At this point best  practice solutions may be considered. | 39 - 39 | Prot-Adapt-Mitig- | | |
| Climate Change and World Heritage - UNESCO 2007 | What do we need to do for cultural heritage? (Monitor, maintain, research etc.)  START HERE END HERE  What do we need to do for natural heritage? (Management etc.)  Choose site Describe evidence Deffne responses Develop Best Practice  of climate change to climate change  Figure 2: Process response to climate change. | 39 - 39 | Prot-Adapt-Mitig- | | |
| Climate Change and World Heritage - UNESCO 2007 | b. Corrective actions: adaptation to the reality of climate  change through global and regional strategies and local  management plans. | 41 - 41 | Prot-Adapt-Mitig- | | |
| Climate Change and World Heritage - UNESCO 2007 | c. State Party / site level actions:  i. Encourage site managers, to the extent possible and  within the available resources, to monitor relevant  climate parameters and to report on adaptation  strategies. | 41 - 41 | Prot-Adapt-Mitig- | | |
| Climate Change and World Heritage - UNESCO 2007 | The very significant challenges which climate change  poses to World Heritage sites can not be effectively dealt  with by any one organization. It calls for a collective  response and the World Heritage Convention, which pro�motes international cooperation for heritage conservation,  can be an effective mechanism for mobilizing such support  from relevant organizations, conventions and processes. | 45 - 45 | Prot-Adapt-Mitig- | | |

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| Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | Coral reefs are ecologically and economically important ecosystems found across the world's tropical and sub-tropical oceans. Despite covering less than 0.1% of the ocean floor, reefs host more than one quarter of all marine fish species (in addition to many other marine animals)1,2. They are the most inherently biodiverse ecosystems in the ocean – comparable to rainforests on land. These 'Rainforests of the Sea' provide social, economic and cultural services with an estimated value of over USD $1 Trillion globally3,4. For example, the complex three-dimensional structure of reefs not only provides habitat but also dissipates wave energy to protect coastlines from erosion and damage. Coastal protection and human use (including tourism, recreation and fishing) supply the greatest economic benefits from coral reefs to over half a billion people around the world. | 3 - 3 | Prot-Adapt-Mitig-Impact | | |
| Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | These impacts lead to reduced habitat for marine organisms that depend upon the reef ecosystem, and fewer ecosystem goods and services, such as food, income and coastal protection, for dependent human communities. | 3 - 3 | Prot-Adapt-Mitig-Impact | | |
| Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | LOCAL MANAGEMENT IS NO LONGER SUFFICIENT TO ENSURE THE FUTURE OF CORAL REEFS. PROTECTING WORLD HERITAGE REEFS REQUIRES COMPLEMENTARY NATIONAL AND GLOBAL EFFORTS TO LIMIT WARMING TO 1.5°C © The Ocean Agency, XL Catlin Seaview Survey, Christophe Bailhache Great Barrier Reef, Wilson Reef<br>10 Impacts of Climate Change on World Heritage Coral Reefs Until now, the focus for World Heritage sites in maintaining the Outstanding Universal Value of their key features has been on maintaining integrity through on-site management and pressures, and national or regional enabling legislation. Efforts to restore resilience and reduce local human stressors remain necessary but are no longer sufficient. For the first time, a ubiquitous global threat - heat stress sufficient to cause frequent severe bleaching and mortality - now threatens the OUV of World Heritage sites in a way that cannot be resolved through local management alone. The only viable solution is for all countries with World Heritage coral reefs to not only act to reduce local stressors but also to reduce their greenhouse gas emissions to net zero, along with supporting active $CO_2$ removal from the atmosphere and upper ocean. | 11 - 12 | Prot-Adapt-Mitig-Impact | | |
| Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | 6. Additional Research This analysis provides a first scientific assessment of past impacts on World Heritage coral reefs and the risks under different emissions scenarios in coming decades. Further work to strengthen and provide a more comprehensive analysis to inform the World Heritage Committee and the global community could include efforts to: f augment historical data collation efforts and expand monitoring of reef condition for all World Heritage properties containing coral reefs; f enhance analysis of past bleaching and heat stress events to test for impacts of back-to-back heat stress or local factors that alter reef resilience; f undertake high-resolution (downscaled) future projection analysis under both RCP2.6 and the new RCP1.9 scenarios, to fully understand the implications of meeting the long�term goal of the Paris Agreement for World Heritage properties. Under RCP2.6 emissions peak during the current decade, 2010-2020, and then decline substantially, resulting in a projected peak global temperature increase of 1.6°C and returning to 1.5°C or below by 2100g . RCP1.9 is being discussed as an emissions pathway that results in a peak global warming of around 1.5°C, and returning to around 1.3°C by 2100; f increase capacity for the detection of impacts on corals, prior to visible signs of bleaching, and how impacts may be alleviated by physical and other mechanisms that confer bleaching resistance and resilience; f expand the consideration of impacts beyond corals, to include broader ecosystem impacts of warming and acidification, and their socio-economic importance; f identify and protect coral reefs (World Heritage or other) that stand in the best position to survive climate change and which are best located to help regenerate other coral communities once ocean conditions have stabilized; and f develop guidance to support the management of World Heritage reefs in the face of climate change, and for industries that depend upon reefs (to enhance social adaptive capacity). | 12 - 12 | Prot-Adapt-Mitig-Impact | INTANBILE | |
| Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | Efforts to build resilience by reducing local human pressure are central to World Heritage conservation, and are matters of concern to the World Heritage Committee, that provides requests and recommendations through the State of Conservation process of the 1972 World Heritage Convention. However, while essential, local management is no longer sufficient to protect the OUV of these properties. | 5 - 5 | Prot-Adapt-Mitig- | | |
| Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | Reduced atmospheric $CO_2$ pathways give corals time to adapt and provide two key opportunities, through: f improving opportunities for adaptation by corals, by reducing the rate of future warming, and extending the window before a critical threshold is reached; and f expanding opportunities for the research and development of new solutions, reducing interacting stressors, developing new models for management, new techniques for rehabilitation, and innovations in industry and manufacturing to reduce $CO_2$ emissions and implement sequestration to remove $CO_2$ from the atmosphere and upper ocean. | 11 - 11 | Prot-Adapt-Mitig- | | |

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| Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | increases this century, and delays the year when a critical threshold is crossed. It also results in eventual stabilization of temperatures and heat stress after 2100. Changing from RCP8.5 to RCP4.5 provides an additional 12 years (on average) of capacity for adaptive responses to occur and reduces the proportion of sites experiencing severe stress levels in any given year. While clearly not enough to 'save' reefs and insufficient as a solution, this is an important opportunity, 'buying time' for natural adaptation, and the search for solutions. Even greater emissions reductions, such as under RCP2.6, and delivering on the Paris Agreement target of "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C"32 offers the only opportunity to prevent coral reef decline globally, and across all 29 reef-containing natural World Heritage sites. | 12 - 12 | Prot-Adapt-Mitig- | | |
| Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | The group of experts prepared a report on "Predicting and Managing the Effects of climate change on World Heritage' (the Report), as well as a 'Strategy to Assist States Parties to the Convention to Implement Appropriate Management Responses" (the Strategy). The Committee reviewed and endorsed these two documents1 at its 30th session (Vilnius, 2006) (Decision 30 COM 7.1), and requested all States Parties to implement the strategy so as to protect the out�standing universal values, integrity and authenticity of the World Heritage properties from the adverse impacts of climate change. | 4 - 4 | Prot-Adapt-Mitig-Impact | | |
| Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | 1 Background CC Policy Doc-eng 13/05/08 16:43 Page 2<br>3 Preamble and purpose According to the IPCC3, the average temperature of the earth's surface has risen by 0.74 degrees C° since the late 1800s4 and it is projected to increase by another 1.1 to 6.4 degrees C° by the year 2099. The sea level rose on average by 10 to 20 cm during the 20th century, and an additional increase of 0.18 to 0.59 cm is projected by the end of the current century5. Small Island Developing States (SIDS) are most vulnerable to such sea level rise and severity of extreme weather conditions and could, in some cases, even become uninhabitable6. With the 4th IPCC Assessment Report (Climate Change 2007) it has been widely acknowl�edged that the scientific basis for understanding the impacts of climate change and options for adaptation and mitigation have been clearly established. | 4 - 5 | Prot-Adapt-Mitig-Impact | | |
| Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Deeply concerned about the adverse impacts which climate change is having or may have on the Outstanding Universal Value (OUV), integrity and authenticity of World Heritage properties, the World Heritage Committee launched an ini�tiative at its 29th session (Durban 2005) to investigate the issue in detail. The resulting report on 'Predicting and Managing the effects of Climate Change on World Heritage', as well as a 'Strategy to assist States Parties to Implement Appropriate Management Responses' were considered and endorsed by the Committee at its 30th ses�sion (Vilnius, 2006)10. These two documents present a detailed analysis of the threats posed to both natural and cultural World Heritage properties by climate change and discuss some of the preventive and corrective actions that 3. Intergovernmental Panel on Climate Change – 'IPCC 4th Assessment Report: Summary for Policymakers'. | 5 - 5 | Prot-Adapt-Mitig-Impact | | |
| Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Mindful of the various issues already covered in detail in the above-mentioned report and strategy, this policy document is principally aimed at providing the World Heritage deci�sion / policy-makers with guidance on a limited number of key issues (synergies, research needs and legal issues). For all other general issues dealing with the impacts of climate change on World Heritage properties and management responses document WHC-06/30.COM/7.1 (World Heritage Paper No. 22) should be consulted. | 6 - 6 | Prot-Adapt-Mitig-Impact | | |
| Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Adaptation: the adjustment in natural or human systems, in response to actual or expected climatic stimuli or their effects that moderate harm or exploit beneficial opportuni�ties (IPCC). | 6 - 6 | Prot-Adapt-Mitig-Impact | | |
| Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | The World Heritage Centre and the Advisory Bodies will cooperate with States Parties and other relevant organiza�tions during the reactive monitoring and periodic reporting processes and in research activities, so that the impacts of, adaptation to, and mitigation of climate change are prop�erly assessed, reported and managed. The use of the UNFCCC Compendium on methods and tools to evaluate impacts of, vulnerability and adaptation to, climate change will be promoted. | 6 - 6 | Prot-Adapt-Mitig-Impact | | |
| Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Some properties may be able to be involved in sequestra�tion and carbon offset activities as part of broader national mitigation approaches and this will be the pri�mary level of focus. They will also integrate these actions in risk preparedness policies and action plans, making use of the 'Strategy for Risk Reduction at World Heritage Properties'12. | 7 - 7 | Prot-Adapt-Mitig-Impact | | |

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| Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | States Parties and managers of individual World Heritage properties will include climate change messages in commu�nication, education and interpretation activities as appro�priate, to build public awareness and knowledge of climate change, its potential impacts on World Heritage properties and their values, and the ongoing activities or available options for adaptation and mitigation. | 7 - 7 | Prot-Adapt-Mitig-Impact | | |
| Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Principles Research on climate change at World Heritage properties will be carried out through partnerships with and influence of those who are conducting or can carry out such research or who fund research programmes. The site-specific nature of the climate change problems facing properties, make them ideal as laboratories for long-term climate change impact monitoring and testing of innovative adaptation solutions. | 7 - 7 | Prot-Adapt-Mitig-Impact | | |
| Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Research must draw wider conclusions or develop approaches (such as management frameworks) that enable knowledge transfer to take place among properties and regions. For example, the approach taken by the EU 6th Framework 12. Document WHC-07/31.COM/7.2 13. http://unfccc.int/files/essential_background/background_publications_htmlpdf/application/pdf/nwp_en_070523.pdf CC Policy Doc-eng 13/05/08 16:43 Page 5<br>6 Programme research project on Global Climate Change Impacts on the Built Heritage and Cultural Landscapes14 in producing a Climate Change Vulnerability Atlas and in developing drying strategies for different types of historic structures for the European Region can be a model for other regions of the world. | 7 - 8 | Prot-Adapt-Mitig-Impact | | |
| Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Three different strands of research needs have been identified: 1. Research that responds to increased risk factors such as fire, drought, floods, avalanches, glacial lake outbursts, to support disaster management plans for properties. | 8 - 8 | Prot-Adapt-Mitig-Impact | | |
| Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Advocacy and implementation Research in relation to the impacts of climate change on World Heritage properties will be linked to a clear course of follow-up action, including awareness raising. In particular the following will be ensured: 1. Research results will be translated into practical tools that can assist managers in developing their adaptive management responses. Options for the creation of a clearing-house mechanism of best-practice case studies on climate change, either separately or linked to similar mechanisms, such as those under the UNFCCC, CBD, UNCCD, or CMS will be investigated. | 8 - 8 | Prot-Adapt-Mitig-Impact | | |
| Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Duties and obligations of States Parties under the Convention Article 4 is a central provision of the Convention: Each State Party to this Convention recognizes that the duty of ensuring the identification, protection, conserva�tion, presentation and transmission to future generations of the cultural and natural heritage referred to in Articles 1 and 2 and situated on its territory, belongs primarily to that State. It will do all it can to this end, to the utmost of its own resources and, where appropriate, with any international assistance and co-operation, in particular, financial, artistic, scientific and technical, which it may be able to obtain. (Emphasis added) 14. http://noahsark.isac.cnr.it/ CC Policy Doc-eng 13/05/08 16:43 Page 6<br>7 In the context of climate change, this provision will be the basis for States to ensure that they are doing all that they can to address the causes and impacts of climate change, in relation to the potential and identified effects of climate change (and other threats) on World Heritage properties situated on their territories. | 8 - 9 | Prot-Adapt-Mitig-Impact | | |
| Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Article 6 of the World Heritage Convention Under Article 6, '…the States Parties to this Convention recognize that [such heritage] constitutes a world heritage for whose protection it is the duty of the international com�munity as a whole to co-operate'. Under Article 6 (3), States Parties undertake 'not to take any deliberate meas�ures which might damage directly or indirectly the cultural and natural heritage'. | 9 - 9 | Prot-Adapt-Mitig-Impact | | |
| Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | • Para 132.4: State of conservation and factors affecting the property: when adverse effects resulting from climate change are evident, climate change will be included as a threat in the description of factors affecting the property, and it will be used as a baseline to monitor the state of conservation of the property in the future. | 9 - 9 | Prot-Adapt-Mitig-Impact | | |

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| Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Periodic reporting Under paragraph 199 of the Operational Guidelines, States Parties are requested to submit reports on legislative and administrative provisions adopted concerning the applica�tion of the Convention, including the state of conservation of their World Heritage properties. The World Heritage Committee will consider a specific obligation for States to report on the climate change related threats and impacts to OUV, and the efforts being made by way of mitigation and adaptation measures to address them. | 10 - 10 | Prot-Adapt-Mitig-Impact | | |
| Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Management planning and management systems Sub-paragraph 5 of para 132 requires the inclusion of a management plan in the nomination submission process, and Para 118 contemplates the inclusion of risk prepared�ness as an element in World Heritage properties manage�ment plans and training strategies. The World Heritage Committee will consider strengthening the management planning and management system provisions of the Operational Guidelines concerning site level adaptation and mitigation measures. | 10 - 10 | Prot-Adapt-Mitig-Impact | | |
| Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | The precautionary approach in World Heritage decision-making in the context of climate change Given the increasing application of the precautionary approach in international law and policy16, the World Heritage Committee will consider specifically incorporating reference to it within the Operational Guidelines. The fact that the approach has been adopted in the UNFCCC pro�vides a useful example, and its application to protection and conservation concerning World Heritage is obvious. The UNFCCC includes this under Article 3 (Principles) as follows: 'The Parties should take precautionary measures to antici�pate, prevent or minimize the causes of climate change and mitigate its adverse effects. Where there are threats of seri�ous or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such meas�ures, taking into account that policies and measures to deal with climate change should be cost-effective so as to ensure global benefits at the lowest possible cost. To achieve this, such policies and measures should take into account different socio-economic contexts, be comprehen�sive, cover all relevant sources, sinks and reservoirs of greenhouse gases and adaptation, and comprise all eco�nomic sectors. Efforts to address climate change may be carried out cooperatively by interested Parties.'17 The explicit adoption of the precautionary approach by the World Heritage Committee as a consideration in decision�making in general will encourage States Parties and the Advisory Bodies to use the emerging knowledge relating to the implementation of the precautionary approach18 to deal more actively with risk and uncertainty when making decisions concerning the effects of climate change on World Heritage properties. | 10 - 10 | Prot-Adapt-Mitig-Impact | | |
| Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | iii. World Heritage properties will be used wherever appro�priate and possible as a means to raise awareness about the impacts of climate change upon World Heritage to act as a catalyst in the international debate and obtain support for policies to mitigate climate change, and to communicate best practices in vulnerability assess�ments, adaptation strategies, mitigation opportunities, and pilot projects. | 11 - 11 | Prot-Adapt-Mitig-Impact | | |
| Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | 5. Research in relation to impacts on integrity (size, shape, boundaries, buffer zones, management, threats, etc.): • To identify key direct and indirect impacts of climate change on the integrity of specific properties and how this research can best be used to guide field manage�ment responses at the site level. | 12 - 12 | Prot-Adapt-Mitig-Impact | | |
| Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | 2. Monitoring change: It is important to recognize that a large amount of data and tools are already available in complementary fields for cul�tural heritage, for example in geo-archaeology and in microbiology. This research needs to be built upon, though clearly specific research is needed because of the general lack of research in climate change impacts and cultural her�itage. There are also currently no standards, protocols, indi�cators and databases within the field of cultural heritage and climate change. This suggests that research needs to focus in two directions: on the impact of climate change on local scales, especially in cities, where there are concentra�tions of people and cultural heritage; and in the develop�ment of new technological tools – advanced yet simple to use on site, to enable monitoring of change and to validate conservation decisions. While sensors need to be both inex�pensive and sturdy, it is important that much progress is made in technology development, with a focus on remote sensing products such as gas phase bio-sensing. This will enable the small group of scientists working in this field to provide remote support to site managers who are prioritiz�ing the managed change of cultural heritage. | 13 - 13 | Prot-Adapt-Mitig-Impact | | |
| Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | It is necessary to assign probabilities of damage to specific properties, but this requires ensembles of climate models to be used and for research to be carried out on sub-grid climate models. This approach would have a much better spatial resolution than the current 50km grid. State-of-the�art computer simulation must be used if site managers are to understand better the potentially catastrophic effect on properties of sporadic and extreme events and to use risk management to forecast the effect of natural disasters on specific World Heritage properties. Research on disaster preparedness must therefore focus on hazard recognition and the quantification and prioritization of climate change risks. | 13 - 13 | Prot-Adapt-Mitig-Impact | | |

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| Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Présentation de rapports périodiques Conformément au paragraphe 199 des Orientations, les États parties sont invités à présenter des rapports sur les dispositions législatives et les règlements administratifs qu'ils auront adoptés pour l'application de la Convention, incluant l'état de conservation des biens du patrimoine mondial situés sur leur territoire. Le Comité du patrimoine mondial envisagera l'obligation spécifique pour les États parties de signaler les dangers et les impacts pour la VUE liés à l'évolution du climat, et les efforts accomplis à travers des mesures d'adaptation et d'atténuation pour y faire face. | 25 - 25 | Prot-Adapt-Mitig-Impact | | |
| Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | The composition and distribution of natural, human and cultural ecosystems are expected to change as species and populations respond to the new conditions created by cli�mate change. Species may be forced to shift their ranges, but this movement becomes difficult or impossible in heav�ily fragmented landscapes7. Climate change exacerbates the incidence of pests, pathogens and fires. Warmer tem�peratures in deserts could threaten species that now exist near their heat tolerance limit, and desertification will increase. The projected declines in glaciers, permafrost and snow cover will affect soil stability and hydrological sys�tems, eventually causing many river systems to dry up. In coastal and marine ecosystems, increased coral bleaching and mortality would profoundly affect the productivity of reef ecosystems8. Thus, climate change will adversely affect, and indeed is already affecting the conservation of World Heritage natural properties9 and the ecological sys�tems that sustain life. | 5 - 5 | Prot-Adapt-Mitig- | | |
| Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | The World Heritage Convention's comparative advantage lies in its management of outstanding cultural and natural heritage properties around the world, and the breadth of States Parties' obligations to protect these properties. | 6 - 6 | Prot-Adapt-Mitig- | | |
| Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Actions taken at these iconic properties attract consider�able attention and can influence the adoption of good management practices elsewhere. Therefore, the World Heritage Centre will focus its efforts on optimizing this comparative advantage by actively promoting, in coopera�tion with States Parties, the use of World Heritage proper�ties in the activities of other conventions, international bodies and programmes working on climate change. | 6 - 6 | Prot-Adapt-Mitig- | | |
| Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Recognizing the overarching objective of safeguarding the outstanding universal values of World Heritage properties, World Heritage properties can serve as laboratories where monitoring, mitigation and adaptation processes can be applied, tested and improved. They can partner with rele�vant organizations in field activities on mitigation and adaptation strategies, methodologies, tools and/or pilot projects. The World Heritage Centre and the Advisory Bodies will lead and coordinate in the collection and wide dissemination of lessons learned and best practice devel�oped through such partnerships. | 6 - 6 | Prot-Adapt-Mitig- | | |
| Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | States Parties and managers of individual World Heritage properties will consider undertaking site-level monitoring, mitigation and adaptation measures, where appropriate. | 7 - 7 | Prot-Adapt-Mitig- | | |
| Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | States Parties may use the opportunities presented by the 'Nairobi Work Programme on Impacts, Vulnerability, and Adaptation to Climate Change'13 under the UNFCCC, and other ongoing processes, to address adaptation to climate change at World Heritage properties. They are encouraged to participate in the United Nations Climate Change confer�ences with a view to achieving a comprehensive post-Kyoto agreement. | 7 - 7 | Prot-Adapt-Mitig- | | |
| Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | States Parties work at the national level, but will also estab�lish appropriate thematic, regional and global linkages and cooperation to understand, access, fund and implement mitigation and adaptation strategies, actions, tools and/or pilot projects. Efforts at World Heritage property level to mitigate and adapt to climate change will be coordinated with other conventions and international bodies working on climate change, to create synergies, integrate activities and avoid duplication. | 7 - 7 | Prot-Adapt-Mitig- | | |

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| Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | These provide the foundation for capacity building for adaptive management among site managers and will receive high priority. In addition, specific research priorities for natural and cultural properties are detailed in the Annex 1 and States Parties will work with appropriate part�ners to support and fund these research needs. | 8 - 8 | Prot-Adapt-Mitig- | | |
| Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | In addition to the duty set out in Article 4, Article 5 places a number of obligations on States Parties: To ensure that effective and active measures are taken for the protection, conservation and presentation of the cul�tural and natural heritage situated on its territory, each State Party to this Convention shall endeavour, in so far as possible, and as appropriate for each country (...) To take the appropriate legal, scientific, technical, admin�istrative and financial measures necessary for the identi�fication, protection, conservation, presentation and rehabilitation of this heritage. | 9 - 9 | Prot-Adapt-Mitig- | | |
| Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | • Para 132.5: Protection and management: relevant provi�sions will be considered to incorporate climate change concerns in the planning and management requirements to ensure adequacy of adaptation and mitigation meas�ures at the site level. | 9 - 9 | Prot-Adapt-Mitig- | | |
| Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | These criteria will be used not only while considering the inclusion of properties on the List of World Heritage in Danger, but will also form the basis for prioritising vulnera�bility assessment, mitigation and adaptation activities. The need for incorporating these criteria into the Operational Guidelines will be considered only after assessing their utility for this purpose. | 10 - 10 | Prot-Adapt-Mitig- | | |
| Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | CC Policy Doc-eng 13/05/08 16:43 Page 8<br>9 Mitigation of emissions by the World Heritage community While the main focus of the response strategy under the World Heritage Convention will be on site-level adaptation, several activities under the Convention and by the World Heritage community result in the emission of greenhouse gases. Therefore, mitigation options will be explored and actions taken for reducing and/or offsetting these emis�sions (e.g. as done in the case of Yosemite National Park, California, USA), and these practices will be publicized. The network of World Heritage cities offers an unparalleled opportunity to promote and highlight the use of energy efficient and carbon neutral technologies. | 10 - 11 | Prot-Adapt-Mitig- | | |
| Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Mitigation measures will also include the following: a recycling program at the World Heritage Centre with pro�gressive, phased targets; progressively increasing use of web- and video-conferencing technologies in order to obvi�ate the need to undertake travel; progressively decreasing paper usage at Committee meetings by encouraging the dissemination and utilization of electronic documents; pro�gressively decreasing the number of air trips on Committee business; measures to ensure that meetings will be carbon�neutral (e.g. Christchurch, 2007); and where airline flights are necessary and unavoidable, the purchasing of carbon offsets from a Gold Standard, including providing meeting budgets with financing for such offsets. | 11 - 11 | Prot-Adapt-Mitig- | | |
| Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | • To identify the climate sensitivity of species and ecosys�tems to provide a greater indication of those values which are most susceptible to climate change (such as from fire, invasive species, drought, etc) and also to identify how much climate change (direction, magni�tude, rate, means vs. extremes) is too much in relation to specific values. Understanding the climatic thresh�olds of key species and communities is essential for planning effective management responses. | 12 - 12 | Prot-Adapt-Mitig- | | |
| Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | 6. Other research in relation to natural World Heritage properties: • To identify how properties contribute to greenhouse gas emissions, sequestration and storage. This could assist in recognizing carbon values of forest and other properties to increase leverage for conservation and potential for sustainable financing through carbon offset projects. | 12 - 12 | Prot-Adapt-Mitig- | | |
| Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | 3. Should the Convention, and its associated Operational Guidelines, seriously consider the fact that for some natural properties it will be impossible to maintain the 'original' OUV for which they were originally inscribed on the World Heritage List, even if effective adaptation and mitigation strategies are applied, therefore requiring an 'evolving' assessment of OUV? | 14 - 14 | Prot-Adapt-Mitig- | | |

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| Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | L'évolution du climat amplifie l'incidence des parasites, des vecteurs pathogènes et des incendies. Le réchauffement de la température dans les déserts pourrait menacer des espè- ces qui ont quasiment atteint aujourd'hui leur seuil de tolé- rance à la chaleur, et la désertification va s'étendre. Le recul projeté des glaciers, du pergélisol et de la couverture neigeuse affectera la stabilité des sols et les régimes hydro�logiques, ce qui finira par provoquer l'assèchement de nombreux cours d'eau. Dans les écosystèmes côtiers et marins, une augmentation du blanchissement et de la mortalité des coraux affecterait profondément la producti�vité des écosystèmes coralliens8. Ainsi, le changement climatique affectera-t-il, si ce n'est déjà fait, la conservation des biens naturels du patrimoine mondial9 et des systèmes écologiques qui soutiennent la vie. | 20 - 20 | Prot-Adapt-Mitig- | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | As this report shows, World Heritage properties provide opportunities for both climate mitigation and adaptation. For example, well-preserved forests and coastal habitats can help store carbon and provide vital ecosystem services, including natural protection against storms and floods. World Heritage sites can also act as learning laboratories for the study and mitigation of climate impacts, as well as being places to test resilient management strategies. | 7 - 7 | Prot-Adapt-Mitig-Impact | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Climate change is both a direct threat and a threat multiplier. Worsening climate impacts are cumulative, and often exacerbate the vulnerability of World Heritage sites to many other existing risks, including uncontrolled tourism, lack of resources for effective management, war, terrorism, poverty, urbanization, infrastructure, oil and gas 12 World Heritage and Tourism in a Changing Climate Box 1 The World Heritage Convention and criteria for selection Adopted in 1972, the World Heritage Convention protects natural diversity and cultural wealth of global significance, the importance of which transcends national boundaries (UNESCO). The roots of the convention lie in efforts during the late 1950s and 1960s to encourage international cooperation to protect cultural heritage and extraordinary natural areas for the benefit of future generations, and for all humankind. | 14 - 14 | Prot-Adapt-Mitig-Impact | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Although there is potential for some species to move and shift their ranges in response to climate change in natural World Heritage sites, and many ecosystems exhibit some degree of climate resilience, adaptive capacity is reduced by other stresses including habitat loss, degradation and fragmentation. The speed of climate change and lack of habitat connectivity will severely limit ecosystem response in many cases, and will require the adoption of new and innovative management practices (Welling et al. 2015; Stein et al. 2014; Markham 1996). | 15 - 15 | Prot-Adapt-Mitig-Impact | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Protecting large intact ecosystems is the most effective way of maintaining the adaptive capacity of natural World Heritage sites. For existing sites this means an increased emphasis on expanding and managing buffer zones and on ensuring connectivity between sites and other protected areas (Kormos et al. 2015). The need to adapt boundaries may be a significant issue for World Heritage sites in a changing climate, and in many technology, monumental arts, town�planning or landscape design; (iii) To bear a unique or at least exceptional testimony to a cultural tradition or to a civilization which is living or which has disappeared; (iv) To be an outstanding example of a type of building, architectural or technological ensemble or landscape which illustrates (a) significant stage(s) in human history; (v) To be an outstanding example of a traditional human settlement, land-use, or sea-use which is representative of a culture (or cultures), or human interaction with the environment especially when it has become vulnerable under the impact of irreversible change; (vi) To be directly or tangibly associated with events or living traditions, with ideas, or with beliefs, with artistic and literary works of outstanding universal significance (the Committee considers that this criterion should preferably be used in conjunction with other criteria); (vii) To contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance; (viii) To be outstanding examples representing major stages of Earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features; (ix) To be outstanding examples representing significant on-going ecological and biological processes in the evolution and development of terrestrial, freshwater, coastal and marine ecosystems and communities of plants and animals; (x) To contain the most important and significant natural habitats for in-situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation. | 15 - 15 | Prot-Adapt-Mitig-Impact | INTANBILE | |

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| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Climate change and the World Heritage Convention It has now been more than a decade since the issue of climate change impacts on natural and cultural heritage properties was formally brought to the attention of the World Heritage Committee (Welling et al. 2015). At its 29th session in Durban, South Africa in 2005, the World Heritage Committee called on States Parties to identify the properties most at risk from climate change and encouraged UNESCO “to ensure that the results about climate change affecting World Heritage properties reach the public at large, in order to mobilize political support for activities against climate change and to safeguard in this way the livelihood of the poorest people of our planet (Decision 29 COM 7B.a). This resulted in a ground-breaking report, Predicting and Managing the Effects of Climate Change on World Heritage (UNESCO 2007b), as well as the Strategy to Assist States Parties to the Convention to Implement Appropriate Management Responses (UNESCO 2007c). At its 30th session (Vilnius, 2006), the World Heritage Committee requested all States Parties to implement the strategy so as to protect the OUV, integrity and authenticity of World Heritage properties from the adverse impacts of climate change. In 2007, at its 16th session, the General Assembly of States Parties adopted a binding Policy Document on the Impacts of Climate Change on World Heritage Properties (UNESCO 2007a). Progress on implementing the strategy and the policy in most countries, however, has been quite limited to date. Furthermore, there has not yet been a comprehensive, science-based assessment of climate impacts and vulnerability at all World Heritage sites. Nonetheless, an increasing amount of data about climate change in relation to World Heritage sites has become available during the last decade or so. | 16 - 16 | Prot-Adapt-Mitig-Impact | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | 14 World Heritage and Tourism in a Changing Climate WH_and_Tourism_23_may.indd 14 H_and_Tourism_23_may.indd 14 24/05/2016 05:25 4/05/2016 05:25<br>Also in 2014, the International Union for the Conservation of Nature’s IUCN World Heritage Outlook declared climate change to be the most serious potential threat to natural World Heritage sites worldwide (Osipova et al. 2014a). Looking more widely at all types of threat, the report also noted that only half of all natural or mixed sites were routinely monitored; more than a third had serious concerns about the levels of conservation; and 13 per cent of sites had ineffective levels of protection and management. Monitoring threats and impacts of all types, including climate change, is critical for ensuring that sites retain their OUV status. In many countries, IUCN found that existing monitoring programmes and management were weak or insufficient (Osipova et al. 2014a). | 16 - 17 | Prot-Adapt-Mitig-Impact | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Official reporting on threats to specific sites under the World Heritage Convention is through state of conservation (SOC) reports produced by the UNESCO World Heritage Centre and the advisory bodies – the International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM), the International Council on Monuments and Sites (ICOMOS) and IUCN. The publicly accessible online World Heritage State of Conservation Information System contains many reports that identify climate-related threats (http://whc.unesco.org/en/soc). During the period 1979–2013, more than 2 600 SOC reports were submitted, with 70 per cent of natural and mixed sites and 41 per cent of cultural sites being assessed at least once. Some 77 per cent of all reports identified management and institutional factors as threats, including a lack of management plans or problems with implementing them; boundary issues; problems with legal frameworks and governance; and scarcity of financial or human resources. The second most reported category of threat was from buildings and development including housing, commercial and industrial India’s Elephanta Caves are one of 130 cultural World Heritage sites identified in a recent academic study as being at long-term risk from sea-level rise. | 17 - 17 | Prot-Adapt-Mitig-Impact | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Three ground-breaking aspects of the Paris Agreement will be vital for the future management and preservation of World Heritage sites. First, the new emphasis on preventing deforestation will increase the importance of forest conservation efforts in World Heritage sites, their buffer zones and surrounding areas. Eighteen Latin American governments at COP21 pledged to use their protected area systems as tools for climate mitigation and adaptation. Key measures include carbon sequestration and preserving ecosystem services to reduce disaster risk, thus highlighting the positive role that natural World Heritage sites can play in national climate strategies. A recent IUCN study found that an estimated 5.7 billion tonnes of forest biomass carbon is stored within natural World Heritage sites in the pan-tropical regions of the world alone (Osipova et al. | 19 - 19 | Prot-Adapt-Mitig-Impact | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Secondly, the Paris Agreement highlighted the need to implement a new international approach to managing climate-driven disasters by shifting from a focus on reducing disaster losses to a comprehensive management vision – building on the Sendai Framework for Disaster Risk Reduction 2015–2030 (UNISDR 2015) – that includes risk assessment, adaptation planning and resilience building. | 19 - 19 | Prot-Adapt-Mitig-Impact | | |

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| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Goal 13 calls for taking "urgent action to combat climate change and its impacts". Goal 14's targets focus on sustainable use and conservation of the oceans, including minimizing and addressing the impacts of ocean acidification; conserving at World Heritage and tourism in a changing climate 17– WH_and_Tourism_23_may.indd 17 H_and_Tourism_23_may.indd 17 24/05/2016 05:25 4/05/2016 05:25 18 World Heritage and Tourism in a Changing Climate least 10 per cent of coastal and marine areas; and increasing the economic benefits to small island developing states through the sustainable use of marine resources, including through tourism. | 19 - 20 | Prot-Adapt-Mitig-Impact | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Responsible tourism can be a driver of sustainable development and the preservation of natural and cultural heritage, but if unplanned and poorly managed it can be socially, economically and culturally disruptive and cause damage and degradation to sensitive ecosystems, landscapes, monuments and communities (WHC 2012). The 2011 ICOMOS Paris Declaration on Heritage as a Driver of Development (ICOMOS 2011) stated clearly that "local participation, drawing on local perspectives, priorities and knowledge, is a pre�condition of sustainable tourism development". | 20 - 20 | Prot-Adapt-Mitig-Impact | INTANBILE | INDG |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Despite the growing body of academic research demonstrating the risks posed to tourism by climate change, concern remains low among tourism operators, with many wrongly believing that there is too much uncertainty around climate impacts to justify action and that adaptation will be relatively easy (Nichols 2014). In fact, adaptation options at many destinations are quite limited and there is an urgent need for the industry to address the issue more seriously. A 2008 report from the UNWTO and UNEP noted that the policy changes and investments needed for effective adaptation may take decades to put in place. The report called on the tourism sector to urgently begin developing and implementing response strategies, especially for destinations most likely to be affected by climate change by mid-century (UNWTO 2008). A recent academic assessment of the implications of the latest climate science for the tourism sector concluded that "the political and business case for a sectoral response on climate change has never been stronger" and "tourism absolutely cannot afford not to ... dedicate increased efforts to understand the implications of climate change" (Scott et al. 2016). | 21 - 21 | Prot-Adapt-Mitig-Impact | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | However, there are often negative impacts associated with uncontrolled or unplanned tourism development, including a lack of visitor access management, cultural disruption and poorly planned infrastructure such as airports, cruise ship terminals and hotels. Such developments can contribute to local environmental problems including excessive water consumption, water pollution, waste generation, habitat damage and threats to local cultures and traditions (UNEP and UNWTO 2012). | 23 - 23 | Prot-Adapt-Mitig-Impact | INTANBILE | INDG |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | In summary, several general conclusions regarding the interaction of climate change and tourism at World Heritage sites can be drawn from an analysis of the case studies: • climate change can have a major negative effect on the attractions and assets that draw tourists to World Heritage destinations and thereby reduce the potential for economic and sustainable tourism development; • over the long term the OUV, integrity and authenticity of some World Heritage sites could eventually be degraded by climate change to the extent that some properties may have to be added to the List of World Heritage in Danger and consideration eventually given to their de-listing; • at World Heritage sites where tourism infrastructure developments and uncontrolled or poorly managed visitor access are already a problem, climate change impacts – for example, extreme weather events, coastal flooding and erosion – are likely to exacerbate problems and increase site vulnerability; • climate change impacts have the potential to increase visitor safety concerns for the tourism industry, especially at sites where increased intensity of extreme weather events or vulnerability to floods and landslides are projected; • national and regional tourism and development strategies and site visitor management plans, with very few exceptions, currently fail to take climate change impacts into account; • climate change is too often regarded as a long�term potential problem for World Heritage sites rather than as an imminent or near-term issue, so assessment of climate vulnerability tends to be under-represented in state of conservation reports; • site managers often lack the financial resources and expertise or training necessary to undertake comprehensive climate vulnerability assessments and the development and implementation of adaptation and resilience strategies. | 28 - 28 | Prot-Adapt-Mitig-Impact | | |

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| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | WH_and_Tourism_23_may.indd 26 H_and_Tourism_23_may.indd 26 24/05/2016 05:25 4/05/2016 05:25 Recommendations 27– T he situation analysis in this report, along with the case studies and site sketches, demonstrates the urgent need to understand, monitor and respond better to climate change threats to World Heritage sites, as well as the interactions between climate change and the tourism sector. The requirements of the binding Policy Document on the Impacts of Climate Change on World Heritage Properties that was adopted by the General Assembly of States Parties to the World Heritage Convention at its 16th session (Paris, 2007), as well as the 2006 Strategy to Assist States Parties to the Convention to Implement Appropriate Management Responses, should be fully implemented. Additional action should be taken to increase the resilience of cultural and natural heritage and reduce the impacts of both climate change and tourism. These recommendations are intended for the international community, States Parties, government policy makers, the tourism industry and site management authorities. | 28 - 29 | Prot-Adapt-Mitig-Impact | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | States Parties are asked to consider site-level monitoring, mitigation and adaptation measures and establish thematic, global and regional links to understand, access, fund and implement mitigation and adaptation strategies. These efforts should be coordinated with other conventions and international bodies. States Parties should work to build public awareness and knowledge of climate change and its potential impacts on World Heritage properties and their values. The policy also calls for more research and research funding partnerships to better understand the consequences and costs of climate change for World Heritage sites as well as for societies, particularly traditional ones, or in sites such as cultural landscapes where the way of life contributes to their outstanding universal value (OUV). Consideration should be given to updating the World Heritage Committee's Strategy to Assist States Parties to the Convention to Implement Appropriate Management Responses in the light of the most up-to-date knowledge on site vulnerability and management options, potential resilience strategies and the latest climate science. Research, including on climate change, should continue to inform the implementation of the convention and management responses. | 29 - 29 | Prot-Adapt-Mitig-Impact | | INDG |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | This review should take account of the interaction of climate change with existing stressors such as tourism pressures, illegal harvesting of natural resources, oil and gas developments, armed conflict and poverty. Systems for monitoring and early warning of climate change impacts should be developed and implemented. UNESCO, working with other international organizations including the United Nations Environment Programme (UNEP), United Nations Development Programme (UNDP), International Labour Organization Recommendations WH_and_Tourism_23_may.indd 27 H_and_Tourism_23_may.indd 27 24/05/2016 05:25 4/05/2016 05:25 28 World Heritage and Tourism in a Changing Climate (ILO), United Nations Industrial Development Organization (UNIDO) and the World Tourism Organization (UNWTO), should prioritize the mapping of impacts using World Heritage properties to field test management strategies and approaches in order to improve resilience and minimize impacts from climate change. | 29 - 30 | Prot-Adapt-Mitig-Impact | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Analyse archaeological data and cultural heritage to use what can be learned from past human responses to climatic change to increase climate resilience for the future Some of the archaeological resources that can provide insights for our future by opening windows on the past are in danger of being lost, particularly in rapidly warming Arctic regions and along eroding coastal and riverine sites. An international response is needed to identify the sites most at risk and to synthesize and use lessons gleaned from the archaeological record and cultural heritage that can help with the development of adaptation strategies for natural and cultural heritage (IHOPE 2015; Jarvis 2014; Rockman 2012). | 31 - 31 | Prot-Adapt-Mitig-Impact | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | GOVERNMENT POLICY MAKERS AND THE TOURISM INDUSTRY Develop strategies and polices that lead to greenhouse gas emission reductions from the tourism sector that are in line with the goals of the Paris Agreement Carbon emissions from transportation and accommodation in the tourism sector are predicted to triple by 2035 and the paucity of technological mitigation options, especially for the rapidly growing long-haul travel sub-sector, means that emissions related to tourism are likely to continue to grow (Fischedick et al. 2014) unless sector-wide action is taken. The response from the industry needs to be on a scale that can match the seriousness and urgency of the problem (OECD 2011). The sector, including the travel and aviation industries, large international tour operators, small businesses, resorts and destinations, must address the issue of its emissions growth. Operators should audit, monitor and reduce their carbon emissions and minimize other environmental impacts. Sector-wide strategies and policies will require the development and adoption of less energy-intensive transportation and accommodation operations and the promotion of sustainable tourism. | 31 - 31 | Prot-Adapt-Mitig-Impact | | |

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| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Create detailed climate change action strategies for tourism management and development at vulnerable sites Multi-stakeholder climate change strategies for tourism should be developed for sites where climate change has been identified as a current or future threat to their OUV, or where climate and tourism impacts together are increasing the vulnerability of the site and local communities. States Parties should work together with site management authorities, local communities, research institutions and the tourism industry to create strategies that: • raise awareness of the OUV of natural and cultural sites and their importance as key assets for the tourism sector; • provide a framework for the tourism industry to respond to climate change, including reducing their own carbon emissions; • engage tourism operators in action that contributes to stewardship in the context of a changing climate; • help to leverage resources in support of climate preparedness and resilience; • provide a coordinating mechanism for government and the tourism industry to address policy and management issues to ensure an adequate response to climate change. | 31 - 31 | Prot-Adapt-Mitig-Impact | | INDG |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | WH_and_Tourism_23_may.indd 29 H_and_Tourism_23_may.indd 29 24/05/2016 05:25 4/05/2016 05:25<br>30 World Heritage and Tourism in a Changing Climate Fully integrate climate change impacts and preparedness into national and site-level tourism planning, policies and strategies The importance to tourism of preserving World Heritage sites in a changing climate must be emphasized, recognized and understood by all involved in tourism planning at the national level, and in the public and private sectors. The management of World Heritage properties for tourism needs to take climate change vulnerability and protection into account. The potential impacts of climate change on the value and integrity of World Heritage sites, as well as the interactions between climate and tourism that could exacerbate negative effects, should be fully considered and integrated into national, regional and local tourism strategies and management. The current lack of integrated cross-sectoral assessments that analyse the full range of potential impacts and their interactions needs to be addressed urgently (Scott et al. 2016). | 31 - 32 | Prot-Adapt-Mitig-Impact | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Site management plans should closely reflect the predicted operational risks and potential impacts of both climate change and tourism. | 32 - 32 | Prot-Adapt-Mitig-Impact | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Develop management tools for collecting data on tourism and climate impacts It is important to develop tools for evaluating the role of heritage and its enhancement in the context of tourism planning and development; to assess the socio-economic cost of the degradation of heritage values and heritage assets resulting from tourism and climate impacts; to help define and test best practices to ensure the long-term preservation of the cultural and economic resource; and to facilitate combined tourism development and climate impact assessment. | 32 - 32 | Prot-Adapt-Mitig-Impact | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Implement polices and action on climate change and tourism that are gender-responsive and participatory Women should have an equal voice in decision making on climate change responses as well as equal access to resources (Perry and Falzon 2014) and economic opportunities in the context of World Heritage management and sustainable tourism. Achieving gender equality and women's empowerment in tourism will increase community resilience to climate impacts (UNESCO 2014). The public and private sectors must take proactive steps to mainstream gender in tourism policy, planning and operations; protect women's rights; and facilitate women's education, leadership and entrepreneurship in tourism (UNWTO 2011). In the preparation of nominations for World Heritage listing, site managers, local communities, national agencies and other stakeholders should document and analyse the experience of women and men in relation to the sites and work together to identify and understand appropriate issues related to gender equality. | 32 - 32 | Prot-Adapt-Mitig-Impact | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | SITE MANAGEMENT AUTHORITIES, INDIGENOUS PEOPLES AND LOCAL COMMUNITIES Fully incorporate the latest climate science and innovation in adaptation strategies into World Heritage site management planning World Heritage site management plans should also incorporate climate research in decisions on planning and implementation relating to the sustainability of sites and their OUV. Tourism management and development strategies should be science-based and make use of the latest data on climate change impacts, vulnerability and resilience. There is also an urgent need to incorporate and better understand the climate exposure and sensitivity of OUV in all World Heritage sites and to incorporate arrangements for climate change adaptation and resilience into management strategies, especially at the most vulnerable sites. UNESCO has developed a methodology to guide development of climate change adaptation strategies and plans at World Heritage sites (Perry and Falzon 2014). Experience gained and lessons learned in implementing these guidelines at site level, as well as from innovative strategies for adaptation and resilience-building being developed by States Parties, will be invaluable. | 33 - 33 | Prot-Adapt-Mitig-Impact | | |

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| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Properties should have effective risk-reduction and disaster-response plans with action priorities in place, and update them regularly based on the latest climate change science. UNESCO's resource manual on managing disaster risks provides valuable guidance for managers and management authorities of cultural and natural World Heritage properties to help reduce the risks to these properties from natural and human-induced disasters (UNESCO 2010). Over the long term, management authorities should shift from planning primarily for disaster response and recovery, to strategies that focus on Recommendations 31– Over at least 2 000 years, the Ifugao people of the Philippines have created a productive landscape of exceptional beauty, but the Rice Terraces of the Philippine Cordilleras are now threatened by climate impacts and cultural change. | 33 - 33 | Prot-Adapt-Mitig-Impact | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | For site risk assessment, it is important to evaluate the widest possible range of impacts, including low�probability outcomes with large consequences (IPCC 2014). Site conservation and management strategies should recognize the inherent potential of sites to reduce disaster risk and adapt to climate change through ecosystem services (Osipova et al. 2014; Renaud and Sudmeier-Rieux 2013; Temmerman et al. 2013). Many World Heritage sites include habitat and ecosystems that serve as natural buffers against climate impacts and other disasters, or play a major role in climate mitigation as carbon stocks and sinks. | 34 - 34 | Prot-Adapt-Mitig-Impact | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Around the world, cultural traditions and indigenous knowledge are being lost. These traditions, vitally important in themselves and also often a significant part of the tourism experience, can be damaged, degraded or lost as a result of both tourist contact and climate impacts. It is crucial to arrest this decline and ensure that adaptation and resilience efforts aimed at preserving World Heritage fully incorporate local voices and maximize the use of local and traditional knowledge. UNESCO, through its Local and Indigenous Knowledge Systems (LINKS) programme, has already gained valuable experience in this field that could be leveraged to benefit the management of World Heritage sites. | 34 - 34 | Prot-Adapt-Mitig-Impact | | INDG |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Establish targeted programmes to raise awareness among tourists, guides, site managers and local communities about the values and protection needs of World Heritage in a changing climate Tourists visiting World Heritage sites represent an important target audience for awareness raising about climate impacts, adaptation and mitigation. | 34 - 34 | Prot-Adapt-Mitig-Impact | | INDG |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | High-quality interpretive materials and programmes can enhance awareness of the risks posed to cultural heritage, wildlife and natural ecosystems from climate change as well as adaptation strategies. Learning about climate change in the locale where its effects are being felt can be a powerful catalyst. Training for tour operators, guides and park rangers can have a magnifying effect. UNESCO's 2009 Strategy for Action on Climate Change identified enhancing public education and awareness about climate change, including encouraging the adoption of sustainable behaviours as a key strategic priority (UNESCO 2009). Innovative programmes involving visitor education and ranger training that could serve as models are being developed by the National Park Service in the USA (USNPS Online). | 34 - 34 | Prot-Adapt-Mitig-Impact | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | WH_and_Tourism_23_may.indd 35 H_and_Tourism_23_may.indd 35 24/05/2016 05:25 4/05/2016 05:25<br>36 World Heritage and Tourism in a Changing Climate In addition to human-caused deforestation, habitat loss and degradation, there is a risk that climate change, together with the expansion of tourism, will increase the probability of disease passing from humans to gorillas. Mountain gorillas are closely related to humans and therefore particularly vulnerable to human diseases. So, whilst tourism has brought many benefits for gorilla conservation and local communities, the proximity of gorilla families that are habituated to tourists increases their risk of exposure to diseases, some of which may be new to them. In Bwindi, habituated gorilla groups have been shown to have a higher incidence of parasites and bacterial infections than non-habituated groups (Kalema-Zikusoka et al. 2005). Even without tourism, however, the habitat overlap between gorillas and people around Bwindi, where there is a dense matrix of agriculture and settlements, has already increased the likelihood of gorillas being infected. | 37 - 38 | Prot-Adapt-Mitig-Impact | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | The importance of refugia Climate change is projected to reduce the Cedrus libani populations to only three refugial zones by 2100, due to higher temperatures and water stress from decreased moisture availability in the Mediterranean region (Hajar et al. 2010a). While plant communities can adapt to climate change by WH_and_Tourism_23_may.indd 43 H_and_Tourism_23_may.indd 43 24/05/2016 05:26 4/05/2016 05:26<br>44 World Heritage and Tourism in a Changing Climate migrating to higher altitudes through seed dispersal and gradual replacement, most of the cedar forests of Lebanon are already isolated on or near mountain summits, with nowhere further upslope to go. The Arz el-Rab stand in the Qadisha valley is an exception, being one of the three cedar forests where there is higher-altitude habitat available for potential migration, which makes their protection all the more urgent (Hajar et al. 2010a). The cedars of Ouadi Qadisha exemplify the vulnerabilities and loss of resilience that plant communities face with habitat degradation and fragmentation. | 45 - 46 | Prot-Adapt-Mitig-Impact | | |

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| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Rice Terraces of the Philippine Cordilleras, Philippines, 1995 (iii), (iv), (v) The indigenous Ifugao people of the Philippine Cordilleras have built and developed their rice terraces over a period of at least 2 000 years. This exceptionally beautiful and important cultural landscape, which draws tourists from all over the world, is highly sensitive to climate change and is already suffering negative effects. Warming temperatures and increases in extreme rainfall events are major problems. More intense rainstorms will increase the instability of the rice terraces built on steep mountain slopes, and cause landslides and erosion. An additional problem is that local rice varieties developed over hundreds of years under stable climatic conditions by the Ifugao are less adaptable to rapid climate change than modern rice strains. Climate change comes on top of cultural perturbations that include the abandonment of rural tradition by young people who are increasingly moving to urban areas. (Manila Observatory; UNESCO f; Katutubo 2015) East Rennell, Solomon Islands, 1998 (ix) Covered in dense tropical forest, Rennell Island is the southernmost of the Solomon Islands in the Western Pacific, and the largest raised coral atoll in the world. The East Rennell World Heritage site comprises 37 000 hectares at the south of the island. The protected area includes the brackish Lake Tegano, the largest lake on any Pacific island. About 1 200 people live in four villages within the property's boundaries and East Rennell was the first World Heritage site to be inscribed with responsibility for its management lying with the traditional and customary owners. East Rennell's outstanding value lies in its undisturbed ecosystems and ecological processes, which make it a natural laboratory for the study of evolution and island biogeography. The integrity of the site as well as its nascent low-impact ecotourism potential are now under threat from commercial logging, the introduction of alien species including the black rat (Rattus rattus), and climate change.<br>Asia and the Paciff c 51– rise is directly affecting Lake Tegano, raising its water levels and salinity. As a result, coconut and taro crops, vital food staples for the local communities, have been significantly reduced, and houses, tourist lodges and the school have been flooded. (UNESCO g) Golden Mountains of Altai, Russian Federation, 1998 (ix) Although the Altai Mountains of Russia were originally listed as a World Heritage site for its biodiversity values, the region is equally important for its incredible cultural and archaeological treasures. | 51 - 53 | Prot-Adapt-Mitig-Impact | | INDG |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Coro was put on the List of World Heritage in Danger in 2005 as a result of significant damage caused by unusually intense rain and storms in 2004 and 2005. The Central America and Caribbean region has been identified as one of the tropical parts of the world most responsive to climate change, and has experienced a marked increase in extreme weather events including droughts, storms and floods over the last 30 years. Increased intensity of periodic rainstorms presents the primary threat to the historic buildings of Coro and La Vela, causing roof leaks, erosion of mud-roof mortar, structural cracking, damp walls, wall collapses and landslides. Major strides in addressing these problems have recently been made through collaborative efforts involving the state, community and traditional artisans. There are positive signs that proactive adaptation strategies can help maintain this important heritage and tourism resource under changing climate conditions. (UNESCOa) WH_and_Tourism_23_may.indd 63 H_and_Tourism_23_may.indd 63 24/05/2016 05:26 4/05/2016 05:26<br>Athousand kilometres off the coast of Ecuador, at the confluence of three Pacific currents, lie the Galápagos Islands, an archipelago of 18 large islands, three smaller ones and more than 100 islets and rocks that are home to a remarkable diversity of species (UNESCOb). | 65 - 66 | Prot-Adapt-Mitig-Impact | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Climate change, particularly in the form of sea-level rise and extreme weather, has more recently become a threat, with changing environmental conditions, landslides and floods following torrential rains, and droughts leading to habitat degradation and loss. Landslides have also caused loss of life in the encroaching urban dwellings all around the forest. Tourism, especially eco-tourism, has brought financial resources and awareness for conservation, and several non-governmental organizations have been working on conservation and adaptation initiatives, including restoration of degraded forests and other habitats to reduce the impacts of various threats. Improved connectivity between forest fragments will be a vital adaptive strategy as the climate continues to change. (GIZ; TNC; UNESCOc) WH_and_Tourism_23_may.indd 70 H_and_Tourism_23_may.indd 70 24/05/2016 05:26 4/05/2016 05:26<br>(GLOFs), with potentially disastrous impacts on nearby communities (Portocarrero 2011). | 72 - 73 | Prot-Adapt-Mitig-Impact | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Sea-level rise, increased storm frequency and intensity, and coastal erosion are major threats to coastal heritage throughout the UK. Some 17 per cent of the UK's coast is eroding and storm damage is expected to increase (Masselink and Russell 2013). Scotland has northern Europe's longest coastline aside from Norway, and conservative estimates suggest that 12 per cent of it is eroding. Of 11 500 archaeological and historic sites surveyed between 1996 and 2011, nearly a third were assessed as needing some sort of action or protection (Dawson 2013). | 81 - 81 | Prot-Adapt-Mitig-Impact | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Archives at risk In Scotland, although Skara Brae is safe for the moment, many other archaeological sites are at risk of destruction by the sea. The threatened sites contain archives of data that can help inform society about human adaptation to previous changes in climate. If no action is taken, however, these archives will be lost. | 81 - 81 | Prot-Adapt-Mitig-Impact | | |

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|---|---|---|---|---|---|
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | As successful as the protection of the area has been over the years, a number of problems remain for which solutions compatible with the sea's protection goals need to be found. In the long term the most important of these may well be climate change and its expected impacts, a major concern in the Wadden Sea region with numerous studies and scientific papers dedicated to this subject. A number of key issues and potential climate change impacts have been identified, including direct effects of sea-level rise, disturbance of natural processes and loss of habitat for many species. | 83 - 83 | Prot-Adapt-Mitig-Impact | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | WH_and_Tourism_23_may.indd 82 24/05/2016 05:48<br>Europe 83– Recognizing that "climate change and enhanced sea-level rise may seriously impact structure, functions and characteristic biodiversity of the Wadden Sea ecosystem, as well as the safety of the inhabitants of the region", in 2014 the Trilateral Wadden Sea Governmental Meeting adopted the Trilateral Climate Change Adaptation Strategy (CWSS 2014b), the overall goal of which is "to safeguard and promote the qualities and the integrity of the area as a natural and sustainable ecosystem whilst ensuring the safety of the inhabitants and visitors". | 84 - 85 | Prot-Adapt-Mitig-Impact | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | The need to act is both urgent and clear. We must reduce greenhouse gas emissions in line with the Paris Agreement while providing the financial resources, support and expertise necessary to ensure the resilience of World Heritage properties over the long term. A growing body of knowledge, management guidelines and policy tools already exists that can help us achieve these goals. Success will require us to expand our networks and partnerships with local communities and businesses and to encourage the tourism industry to join us in this vital task. | 7 - 7 | Prot-Adapt-Mitig- | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | The concept of World Heritage, and the vital importance of linking natural and human systems and maintaining the balance between the two, is now well understood and supported worldwide. The World Heritage Convention helps bring attention to the world's most iconic and important cultural and natural heritage, provides support for management planning and implementation and monitors the state of conservation of the properties on the list. Inclusion on the World Heritage List can help drive tourism to properties, which if managed in accordance with principles of sustainable development can provide important economic benefits to local communities and national economies. | 14 - 14 | Prot-Adapt-Mitig- | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | 2016). One small step forward has been made since Paris. In February 2016, the Committee on Aviation Environmental Protection of the International Civil Aviation Authority for the first time issued a recommendation for a CO2 emissions standard for aircraft that could be strengthened over time (ICAO 2016). | 20 - 20 | Prot-Adapt-Mitig- | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | A recent study by the US National Park Service of the historical correlations between temperature and its 270 million annual visits showed that there is a strong relationship between climate conditions and park visitation. The study showed that park visits tend to increase with warmer weather, but that at temperatures of 25ºC or above they significantly decrease. The authors suggest that climate change will have a large and potentially quite complex role in altering visitation patterns at protected areas worldwide and that managers need to take this into account in management and adaptation planning (Fisichelli et al. 2015). | 21 - 21 | Prot-Adapt-Mitig- | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Adaptation capacity in the tourism sector will vary. It is likely to be especially hard for communities and operators with large investments Changes in populations of fynbos pollinating species, such as this Cape sugarbird feeding on a king protea, could have major implications for the ecosystems of the Cape Floral Region Protected Areas of South Africa. | 21 - 21 | Prot-Adapt-Mitig- | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | World Heritage and tourism in a changing climate 19– WH_and_Tourism_23_may.indd 19 H_and_Tourism_23_may.indd 19 24/05/2016 05:25 4/05/2016 05:25<br>20 World Heritage and Tourism in a Changing Climate in infrastructure such as hotels, resorts, harbours and airports. These could become stranded assets, especially in heavily affected coastal areas. For all destinations, disaster preparedness and management will become an increasingly important part of any destination's integrated management plans as climate-related disasters worsen. Least developed countries, however, are more vulnerable to extreme events than richer ones, and so liable to suffer more. | 21 - 22 | Prot-Adapt-Mitig- | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Almost all World Heritage sites are or become tourist destinations – some are among the most iconic places on Earth – and the objective of the World Heritage Convention is to protect sites of outstanding universal value for future generations. States Parties are required to "present" World Heritage properties to the public, and the inscription of a site on the World Heritage List brings responsibilities for protection as well as opportunities for community and economic progress through sustainable development (WHC 2010). | 22 - 22 | Prot-Adapt-Mitig- | | |

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|---|---|---|---|---|---|
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | At its General Assembly meeting in Mexico in 1999, ICOMOS adopted the International Cultural Tourism Charter (ICOMOS 1999) with the objective of improving the relationship between host communities and the tourism industry. The charter principles, whilst not specifically designed for World Heritage sites, address some relevant management issues that can provide important guidance at the site level, for example on sensitivity to the needs of local communities, managing potential conflicts, site interpretation and tourism promotion. | 24 - 24 | Prot-Adapt-Mitig- | | INDG |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Because of their international designation and the resulting resources and attention they receive, World Heritage sites have the potential to provide some of the best models and innovative examples of sustainable tourism. In order to realize that potential, however, and preserve the OUV that defines sites as so transcendentally important for future generations, sustainable and adaptive management strategies should be instituted to help make sites more resilient to climate change. | 24 - 24 | Prot-Adapt-Mitig- | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | UNESCO has produced a practical guide on climate change adaptation for natural World Heritage sites to help site managers better understand how climate change may affect the OUV of the sites and offer ideas for adapting to climate change with tailored management responses (Perry and Falzon 2014). Governments, too, are beginning to integrate climate issues with tourism planning. The best of these strategies have been collaboratively developed by protected area managers, scientists and public and private tourism stakeholders working together (GBRMPA 2009). | 24 - 24 | Prot-Adapt-Mitig- | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Gender issues in global tourism and climate change response at World Heritage sites Gender equality is one of UNESCO’s two global priorities (Olsson et al. 2014; WHO 2011). As women make up a large proportion of the tourism workforce, their full and equal involvement in climate preparedness and management strategies WH_and_Tourism_23_may.indd 22 H_and_Tourism_23_may.indd 22 24/05/2016 05:25 4/05/2016 05:25 associated with World Heritage sites and tourism destinations is vital. Even though women in tourism earn 10–15 per cent less on average than their male counterparts (UNWTO 2011), tourism can still offer them significant economic and leadership opportunities. The sector has almost twice as many female employers as any other economic sector, as well as a much higher proportion of self-employed women working on their own (UNWTO 2011). | 24 - 25 | Prot-Adapt-Mitig- | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Indigenous and local knowledge and cultural traditions can contribute to climate resilience There is widespread recognition that indigenous and local populations have unique and valuable local knowledge, traditions and cultural practices that can contribute to effective management strategies in the face of rapid climatic change. | 26 - 26 | Prot-Adapt-Mitig- | INTANBILE | INDG |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Living cultural heritage is a vital resource for climate adaptation in and around World Heritage sites, and some aspects, including arts and crafts, dances and traditional agricultural practices, are increasingly popular draws for tourists, too. | 26 - 26 | Prot-Adapt-Mitig- | INTANBILE | INDG |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Many communities living in and around World Heritage sites, however, have developed a wealth of intangible cultural heritage in the form of knowledge and traditions associated with the sustainable management of biodiversity, forests, wetlands and marine resources, often over hundreds or even thousands of years. | 26 - 26 | Prot-Adapt-Mitig- | INTANBILE | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Drawing on knowledge built up over generations, local community members can often observe and interpret climate phenomena in a different way, and at a richer and finer scale than can be done by scientists (Goswami 2015). It is commonplace for such traditional knowledge to be overlooked or ignored in planning and administrative decisions. There is, however, a growing number of World Heritage sites where local knowledge and community-based decision making are providing new models of resilience and adaptation. On the Pacific Island of Vanuatu, for example, traditional subsistence and construction practices, along with support networks based on kinship and exchange, form the foundation of cyclone preparedness and response strategies for the nation’s sole World Heritage property, Chief Roi Mata’s Domain (Ballard et al. 2015). | 26 - 26 | Prot-Adapt-Mitig- | INTANBILE | INDG |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | The practical experience deriving from the Community Management of Protected Areas for Conservation (COMPACT) initiative at several other World Heritage sites – including Tanzania’s Mount Kilimanjaro and the Belize Barrier Reef – demonstrates that the involvement of indigenous peoples and local communities leads to management effectiveness and improved governance (Brown and Hay-Edie 2014). | 26 - 26 | Prot-Adapt-Mitig- | | INDG |

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| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | All of the case study sites are nationally or regionally important for tourism, and several of them are iconic global tourist destinations, including the Galápagos Islands, Ecuador; Venice and its Lagoon, Italy; and Yellowstone National Park, USA. In addition to the case studies, the report includes information on 18 more World Heritage sites where climate change and tourism management issues interact and for which short sketches are provided to give a broader view of the situation around the world. Together, these provide a sample of World Heritage sites – with a range of low, medium and high levels of tourism development in 29 countries – that are already being affected by climate change or are likely to be highly vulnerable to it in the near future. | 27 - 27 | Prot-Adapt-Mitig- | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | To put these cases in context, the amount available to States Parties requiring international assistance to support site management through the World Heritage Fund totals just US$ 4 million – a drop in the ocean given the scale of response needed for the challenge of climate change. | 28 - 28 | Prot-Adapt-Mitig- | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Whilst several case-study sites have robust and successful visitor management strategies, few have attempted to comprehensively integrate both climate change and tourism into long-term sustainability planning. The conservation strategy for the Wadden Sea, along the coasts of Denmark, Germany and the Netherlands, provides one of the best examples of this philosophy in action. | 28 - 28 | Prot-Adapt-Mitig- | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | To strengthen resilience to climate change, increase the inclusion of wilderness areas on the World Heritage List, ensure connectivity between sites, and increase resources for protected area management Protecting large intact ecosystems is the most effective way of maintaining the adaptive capacity of natural World Heritage sites. For existing sites this means putting greater emphasis on expanding and managing buffer zones and on ensuring connectivity between sites and other protected areas (Kormos et al. 2015). Increasing the inclusion of wilderness areas with outstanding universal value within the World Heritage Convention will help maintain the large-scale ecosystem processes and biological diversity that are essential for adaptation and resilience in a changing climate and for maintaining the integrity of many sites (Kormos et al. 2015). Governments with protected areas already inscribed on the World Heritage List should step up implementation of existing management plans and policies already established under the World Heritage Convention or other multilateral agreements such as the Ramsar Convention on Wetlands and the Convention on Biological Diversity (Watson et al. | 30 - 30 | Prot-Adapt-Mitig- | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Urgently address the issue of inadequate resourcing for World Heritage site management and climate adaptation Inadequate resourcing is the leading cause of poor performance in protected area management (Watson et al. 2014). Lack of resources, including financing, personnel, training and capacity building, represents the greatest barrier preventing effective management of World Heritage sites, including the assessment of their vulnerability to climate change, developing and implementing climate adaptation and resilience strategies, and planning and managing tourism development. Until World Heritage sites receive adequate public- and private�sector funding and resources, they will struggle to meet their preservation objectives. The tourism industry can demonstrate leadership by developing and participating in innovative partnerships that bring new financing in support of World Heritage site management. | 30 - 30 | Prot-Adapt-Mitig- | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | In view of limitations on human and financial capacity in many developing countries, the task of managing and monitoring World Heritage sites will need to be widened to other sectors such as tourism. The use of innovative and layered approaches involving multiple partners and stakeholders pooling their talents and resources will improve short- and long-term planning, and strengthen monitoring and protection efforts. The coordination capacity of national World Heritage authorities will also require assistance and support from key tourism stakeholders. In particular, tourism promoters and management agencies must be tasked with raising the levels of awareness in their value chains of the vulnerabilities of World Heritage sites and encouraging a coordinated response. | 32 - 32 | Prot-Adapt-Mitig- | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Develop tourism investment guidelines that encourage inclusive and equitable development The development of tourism in and around World Heritage sites should be accompanied by inclusive and equitable economic investment policies (UNESCO 2015). Efforts should also be made to ensure that local communities share equitably in the economic benefits of tourism and that a portion of revenues is re-invested in the management of World Heritage sites and their resilience to climate change. The Community Management of Protected Areas for Conservation (COMPACT) initiative provides a concrete method WH_and_Tourism_23_may.indd 30 H_and_Tourism_23_may.indd 30 24/05/2016 05:25 4/05/2016 05:25<br>and examples for establishing benefit-share programmes for World Heritage sites (Brown and Hay-Edie 2014). | 32 - 33 | Prot-Adapt-Mitig- | | INDG |

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| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Ensure that indigenous peoples and local communities are fully involved at all stages of climate adaptation and tourism development Utilizing local and traditional knowledge systems for effective adaptation of World Heritage sites is vital in the face of climate change. It is also essential to empower and support local descendent and traditional communities to maintain and preserve what they value, including intangible heritage and subsistence lifestyles (UCSUSA 2014). | 34 - 34 | Prot-Adapt-Mitig- | INTANBILE | INDG |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | This ensures that adaptation strategies contribute to the well-being of the communities, including marginalized groups, and avoids widening existing inequalities (Perry and Falzon 2014). | 34 - 34 | Prot-Adapt-Mitig- | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Increase collaboration on site management planning and operations with tourism stakeholders Where relevant, collaboration with the tourism sector should be a priority for site managers, with attention given to controlling visitor levels and joint activities aimed at conveying accurate information about the site's OUV. Using certification tools such as ISO14001, the Global Sustainable Tourism Criteria and other sustainability standards can strengthen site management planning and operations. | 34 - 34 | Prot-Adapt-Mitig- | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Minaret and Archaeological Remains of Jam, Afghanistan WH_and_Tourism_23_may.indd 32 H_and_Tourism_23_may.indd 32 24/05/2016 05:25 4/05/2016 05:25<br>Case studies WH_and_Tourism_23_may.indd 33 H_and_Tourism_23_may.indd 33 24/05/2016 05:25 4/05/2016 05:25<br>34 World Heritage & Tourism in a Changing Climate J ust under half of the world's remaining endangered 880 mountain gorillas (Gorilla beringei beringei) live in southwestern Uganda's Bwindi Impenetrable Forest National Park (IGCC 2011). Gorillas are iconic and their populations here and in their other stronghold in the Virunga Mountains on the borders of Uganda, Rwanda and the Democratic Republic of Congo, have been increasing in recent decades as a result of effective forest management and protection strategies (IGCC 2011). These efforts have been helped by revenue from gorilla tourism in both Rwanda and Uganda. | 34 - 36 | Prot-Adapt-Mitig- | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | All indications are that rising temperatures and changes in rainfall regimes will increase stress on gorilla populations, exacerbating the immediate threats posed by habitat degradation, rising tourism and the proximity of rural communities and their expanding populations. Effective ongoing management of Bwindi Impenetrable National Park, its buffer zones and other protected areas as core areas for gorilla conservation is an essential conservation strategy. To support this, it will be vital to maintain the flow of tourism dollars to conservation programmes and local communities. | 39 - 39 | Prot-Adapt-Mitig- | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | It is clear that future prospects for this important biodiversity hotspot and tourism centre will be under pressure in an increasingly warm and dry climate. Preservation of the fynbos biome and its extraordinary array of species will depend on careful management of buffer areas, reduced stress from wildland conversion and perhaps increased connectivity of protected areas, even if global mean temperature increase can be kept to 2ºC or below. | 43 - 43 | Prot-Adapt-Mitig- | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Plan 4C's vision states: "by the year 2040, the historic heritage of Cartagena de Indias will be resilient to climate change. This will be made possible by carrying out actions within the framework of climate compatible development, maintaining its value as a World Heritage City and a Cultural Interest Asset for the people of Cartagena and visitors" (OMCI et al. 2014). The plan outlines key measures needed to achieve this vision, among which is the protection of assets of cultural interest, revitalization of public spaces, development of sustainable transport, promotion of energy efficiency, and adoption of land management and financial instruments. As outlined in the plan, historic heritage protection entails both mitigation and adaptation strategies. | 65 - 65 | Prot-Adapt-Mitig- | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | The adaptation strategies include the development of a work plan for cultural asset protection to prevent flooding in the historic centre, as well as for the restoration and preservation of buildings. | 65 - 65 | Prot-Adapt-Mitig- | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | First colonized by Ecuador in 1832 and most famously visited by Charles Darwin in 1835, the islands are known worldwide for the role their species, particularly the finches (Fringillidae), played in helping Darwin form his theory of evolution by natural selection. The islands are now one of the world's hotspots for wildlife tourism and are struggling to balance increasing visitor numbers and infrastructure development with conservation imperatives. | 66 - 66 | Prot-Adapt-Mitig- | | |

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| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | The original management plan of 1973 established a maximum of 12 000 visitors per year, but that has been constantly revised upwards and, in 2013, 205 000 people visited the islands (Parque Nacional Galápagos). Galápagos tourism generates US$ 418 million annually, of which US$ 61 million enters the local economy, fully 51 per cent of the islands' revenue (Galápagos Conservancy a). The resident population of the islands was around 4 000 in the 1970s, but demand for visitor services has been a big driver of rapid growth – the population doubled between 1991 and 2005 and today it stands at around 25 000 people (Galápagos Conservancy b). | 66 - 66 | Prot-Adapt-Mitig- | | |
| World Heritage and Tourism in a Changing Climate - UNESCO 2016 | In 2015, initial thoughts about how to prepare for accelerating sea-level rise and identify the right steps for action were developed in more detail for the Schleswig-Holstein part of the Wadden Sea, covering about one third of its entirety. The regional government adopted the Strategy for the Wadden Sea 2100 (MELUR-SH 2015), which had been developed by a stakeholder group consisting of the coastal defence and national park administrations, and representatives from the island communities and two environmental non-governmental organizations including the global conservation organization WWF. | 85 - 85 | Prot-Adapt-Mitig- | | |

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# Atlas.ti 22 Raw Data

| Organisation | Document | Quotation Content | Codes | Page |
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| UNESCO | Adapting to Change (2011) | a Forest World Heritage Site – Renata Krzyciak-Kosiska . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 74 World Heritage Sites, Biosphere Reserves and Model Forests: Connecting Mesoamerica – Eduard Muller and Marc Patry . . . . .80 Multi-actor Partnership and Sustainability Management of Biodiversity: The Case of the World Heritage Site . . . . . . . . . . . . .86 of the Dja Faunal Reserve (DFR) – Gustave Ossie Ompene, Patrice André PA'AH, Théophile Bouki, Jean-Claude S. Njomkap, Julie Gagoe Tchoko and Mariteuw Chimère Diaw Ecological Integrity and Sustainable Development in the Chiquitano Dry Forest of Bolivia . . . . . . . . . . . . . . . . . . . . . . . . . .91 – Roberto Vides-Almonacid and Hermes Justiniano Annexes . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 97 I. World Heritage Forest Indicator Database . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 98 II. World Heritage Forests - Inscription and Geographical Characteristics . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 102 III. Reporting Trend for World Heritage Forests, 2001-2011 . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 107 IV. Forests Previously Identified for Potential Inclusion onto the World Heritage List – Romy Horn . . . . . . . . . . . . . . . . . . . . . . . 111 V. World Heritage Forest Sites Coinciding with Ramsar Sites and/or Biosphere Reserves . . . . . . . . . . . . . . . . . . . . . . . . . . . . 112 VI. Cultural World Heritage Sites with Significant Forest Cover – Nicholas Flack . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 114 Contents 1 2 3 4 Joint Foreword . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 3 Irma Bokova Sha Zukang Introductory Remarks Kishore Rao . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 5 Jan McAlpine . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . 7<br>11 State of Conservation of World Heritage Forests in 2011 1 Cloud forests of the Talamanca Range – La Amistad Reserves / La Amistad National Park (Costa Rica, Panama) © UNESCO/ Patry<br>Introduction It sometimes seems that forests are stuck in an Alice in Wonderland world, running faster and faster just to stay in the same place. But it is actually worse than that, because some of the world's most important forests are seriously threatened by overharvesting, road-building, habitat loss and so forth. The authoritative Global Forest Assessment (2010) reported an annual net loss of 5.2 million hectares of forest over the past decade, a somewhat lower rate than the previous decade but this annual loss still totaled almost as much as the total forest area protected as World Heritage forests. | Impacts | 9 - 11 |
| UNESCO | Adapting to Change (2011) | While the rate of destruction may have slowed, and the growth of plantations increased, the latest word from the Brazilian Amazon is that the rate of loss there was about six times worse in 2010 than it was in 2009 - after 2009 had been celebrated because the rate of forest loss in the Amazon had been significantly reduced. | Impacts | 11 - 11 |
| UNESCO | Adapting to Change (2011) | But think about it: slowing the global rate of loss simply means that it will take somewhat longer for the world's forests to be converted to other uses, perhaps leaving only the World Heritage forests to remind us of the past glories of the world's richest terrestrial ecosystems. | Impacts | 11 - 11 |
| UNESCO | Adapting to Change (2011) | The northern forests covering millions of hectares are now being reduced to kindling, awaiting the devastation of forest fires such as those that ravaged Russia in 2010 with damage Pravda (2010) estimated at US$ 15 billion from some 7,000 fires spread over an area greater than one million hectares; and in May 2011, wildfires destroyed some 297,000 hectares of Russian forest, almost twice the rate of loss in 2010. As discussed in the chapter by Perry (this volume), climate change is adding a profound new threat to the usual litany of threats to forests, and is highly likely to have negative impacts on the outstanding universal value of many forested sites now listed on the World Heritage List. Small wonder that a disproportionate number of World Heritage forest sites are listed as World Heritage in Danger (Patry and Horn, this volume). Or perhaps the real wonder is that more World Heritage forests are not listed as 'in danger', because they almost certainly are living on borrowed time. | Impacts | 11 - 11 |
| UNESCO | Adapting to Change (2011) | The dynamic history of forests Forests often seem eternal, stable representations of mature and stately ecosystems. But the venerable concept of relatively stable 'climax' forest ecosystems that are hundreds, or even thousands, of years old has now been replaced by the recognition that forests are in a constant state of change, requiring more adaptive forms of management (Hollings, 1978). Resource managers now need to consider the dynamic forces of fires, storms, droughts, climate change, and other natural factors with the usual human impacts such as logging, introduction of non-native species, building of roads, planting of vast plantations of genetically identical trees, and so forth. | Impacts | 11 - 11 |

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| UNESCO | Adapting to Change (2011) | Isolating a forest by excessive land use changes around it will have significant repercussions on its ability to maintain its composite biodiversity and to provide ecosystem services, rendering it more susceptible to disturbance. In this regard, no forest is an island. Ironically, in strictly legal terms, World Heritage forests tend to be managed as if there were islands. They must be designated with bound�aries that indicate which government agency has responsi�bility for maintaining its World Heritage values. As a result, though a forest is extensively connected to the lands around it, management is often designed as though they were closed systems and it is often forced to function with little interaction or mandate to engage with landscape level stakeholders who may have an influence on systems, which in turn may affect World Heritage forests. The long�term well being of World Heritage forests is therefore at risk from both ecological and institutional isolation. | Impacts | 12 - 12 |
| UNESCO | Adapting to Change (2011) | But connectivity also carries some hazards. A process that can help grizzly bears to move more widely can also be used by various pest species to move more extensively, freed from their dispersal barrier of inappropriate habitats. | Impacts | 12 - 12 |
| UNESCO | Adapting to Change (2011) | The evolutionary forces of isolation may be disrupted, fires may find it easier to spread, and disease may no longer be impeded by buffer zones. These risks will need to be incor�porated, as connectivity becomes a more central concern in forest management (Ewers and Kapos, this volume). | Impacts | 12 - 12 |
| UNESCO | Adapting to Change (2011) | One study of over 160 extreme events found that a 10 per cent loss of native forest cover increased flood frequency by 2.9–25.3 per cent, the number of people killed by 1.0–6.9 per cent, and people displaced by 0.7– 5.1 per cent (Bradshaw et al., 2009). The ecosystem service of protecting people against extreme climatic or geological events may in a sense lie beyond economic value, as it requires putting a price on human life. | Impacts | 13 - 13 |
| UNESCO | Adapting to Change (2011) | Much of this volume is rightfully devoted to the impacts of human induced climate change on forests, and the economic response to those impacts, especially the approach that has come to be known as REDD, or more recently, REDD+. The acronym stands for Reducing Emissions from Deforestation and Forest Degradation, but the original idea implied that carbon sequestration was the only objective, opening the possibility of replacing old�growth forests with non-native fast-growing species like eucalyptus. It soon became apparent that REDD could be applied far more broadly and include many other forest values, as well as providing strong support to old-growth forests with high biodiversity values (Phelps and Webb; Entenmann and Schmitt, this volume). These additional values form the '+', and World Heritage forests offer an ideal opportunity for demonstrating how funds linked to climate change can be used to conserve old-growth forests through REDD+. Indonesia's Tropical Rainforest Heritage of Sumatra is already benefiting from this process, and could be a useful pilot project for testing some of the complexities involved in REDD+, especially ensuring that forest dwelling people receive their fair share of the benefits (Hirsch et al., 2010; Phelps et al., 2011). | Impacts | 13 - 13 |
| UNESCO | Adapting to Change (2011) | 14 11 Adapting to Change – The State of Conservation of World Heritage Forests in 2011<br>Reducing external impacts on World Heritage forests Global demand for forest products continues to expand, though the rate of increase is surprisingly modest, increasing by only 0.4 per cent per year since 1980. But over the same time, paper consumption increased at an annual rate of 3.2 per cent, and sawn timber and wood panels increased by 0.8 per cent per year (Ajani, 2011). | Impacts | 13 - 14 |
| UNESCO | Adapting to Change (2011) | Pravda. 2010. Russian forest fires cause over $15 billion in damages. | Impacts | 15 - 15 |
| UNESCO | Adapting to Change (2011) | Settele, Josef, et al.. 2008. Climatic Risk Atlas of European Butterflies. | Impacts | 15 - 15 |

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| UNESCO | Adapting to Change (2011) | References IUCN. 2004. The World Heritage List: Future priorities for a credible and complete list of natural and mixed site. IUCN, Gland. Available online: http://whc.unesco.org/uploads/activities/documents/ activity-590-3.pdf UNESCO. 2007. World Heritage Forests – Leveraging Conservation at the Landscape Level. World Heritage Report 21. UNESCO, Paris. Available online: http://whc.unesco.org/uploads/activities/documents/ activity-43-8.pdf State of Conservation of World Heritage Forests in 2011 21 1 Reporting trend value Year 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 28.0 27.5 27.0 26.5 26.0 25.5 25.0 24.5 24.0 23.5 23.0 22.5 22.0 21.5 21.0 20.5 20.0 Figure 6. Reporting trend for World Heritage forest sites<br>23 Adapting to changes 2 Boreal forests of Gros Morne National Park, Canada © Lisa Liscoumb<br>Overview Managers of World Heritage forests are facing a poorly recognized crisis. Climates are changing all over the world and we are seeing increased frequencies of floods, droughts, and severe storms. As climates change, ecosystem constituents react differently, some species expanding their ranges, some contracting them. As climates change, a World Heritage forest may also become more vulnerable to human induced impacts, compounding stresses. Taken together, these stresses and changes may lead to the loss of those values for which a site was origi�nally recognized under the World Heritage Convention. | Impacts | 20 - 22 |
| UNESCO | Adapting to Change (2011) | Assessing climate change It is critical today that site managers, national govern�ments, and UNESCO refine existing monitoring and assess�ment (M&A) programmes to include the detection of climate change related impacts in World Heritage forests. | Impacts | 22 - 22 |
| UNESCO | Adapting to Change (2011) | Adapting to climate change Once monitoring has provided information on changes taking place, the next and more complex challenge lies in implementing effective adaptation measures. All ecosys�tems change through time. The challenge facing us today is to understand where changes will threaten the Outstanding Universal Values that qualify a site as World Heritage, and understand if and how we can do some�thing about it, and when we cannot, then act on that information. Adaptive strategies include land management (i.e. establishing ecological corridors to allow the migra�tion of plants and animals, and buffers to increase the resilience of sites), on-site management (i.e. encouraging or discouraging vegetative patterns), and management of human impacts (i.e. fire risk). It is likely that a systematic and full response to climate change for all World Heritage forest sites will be restricted by financial capacity. To prior�itize action, the sites that are at highest risk, the drivers of that risk, and those with potential for greatest adaptive opportunities, all need to be identified. | Impacts | 22 - 22 |
| UNESCO | Adapting to Change (2011) | Therefore, there will always be uncertainty about a predicted future. That uncertainty requires adaptive management (i.e. taking action on the ground, measuring effects, and changing management as necessary). It also requires being routinely aware of the growth in model effectiveness, so that management is based on reasonable climate scenarios. | Impacts | 23 - 23 |
| UNESCO | Adapting to Change (2011) | Adapting to changes 25 2 Defining Vulnerability Overall vulnerability of a site is expressed by combin�ing a range of variables and comparing many sites to each other. Variables that are thought to influ�ence the vulnerability of a World Heritage forest to climate change include size, susceptibility to sea level rise, fragmentation, patch size and distribu�tion, mountainous landscape, insular nature, aggres�sive land use and elevation and distance away from the coast (Perry, 2011). There is no threshold for these variables. Vulnerability in this context sug�gests that the probability of a negative impact due to climate change is relatively high, among World Heritage forests. | Impacts | 23 - 23 |
| UNESCO | Adapting to Change (2011) | The influence of nearby human population centres Human activity adjacent to, and in some cases within a World Heritage forest will have significant impacts on that ecosystem and will influence its vulnerability to climate change. Human influence on a World Heritage forest is influenced by a range of variables, such as proximity to transportation corridors, population centres, and the nature of surrounding land use. The Human Influence Index (HII4, Sanderson et al., 2002) developed by CEISIN at Columbia University uses the most recent data available to combine eight major variables into one index. The HII is a useful tool for comparing sites in a region or for tracking changes through time (Leroux et al., 2010). The HII ranges from 0 to 64 globally; it ranges from 0 to 33, and averages 15.1 in World Heritage forests. | Impacts | 24 - 24 |
| UNESCO | Adapting to Change (2011) | Proactive strategies might include developing co-manage�ment strategies for adjacent lands, or investing resources in assessment and education to ensure that people in adjacent communities understand the value of the site, as well as the probability and significance of a potential, climate change related impact. | Impacts | 24 - 24 |

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| UNESCO | Adapting to Change (2011) | Monitoring An innovative monitoring programme will return great divi�dends. For example, ecological monitoring at especially sensitive or indicative locations within a site (i.e. at a forest�grassland border, along an elevation gradient, or along a glacier's leading edge) may serve as early warning of climate related changes. Aquatic communities within forest ecosystems integrate many landscape characteristics and can serve as highly sensitive indicators. The most effective ecological monitoring programmes will be integrative among ecosystem components, and will target landscape characteristics such as edges and transitional zones, where climate change effects are likely to be first noted. | Impacts | 25 - 25 |
| UNESCO | Adapting to Change (2011) | The most significant decision to be made regarding climate change adaptation and ecological monitoring is the audience for the results, and the actions one wishes that audience to take. A proactive climate-change response plan for a World Heritage forest should include stakeholder definition (i.e. who are the people who care about and have the ability to act upon impacts of climate change at the site?). A monitoring programme, including both climatic and ecological variables will inform those stakeholders and guide their actions. An actively engaged site manager will be able to provide data and information about his/her site, and the ways climate-related changes are affecting that site, or might affect it in the future. A stakeholder group will be able to develop and assess large scale adaptive strategies such as the purchase or manage�ment of adjacent lands, the formulation of land use poli�cies designed to encourage certain behaviours among land owners, or management of human impacts (i.e. better fire control capacity). | Impacts | 25 - 25 |
| UNESCO | Adapting to Change (2011) | A serious constraint faced by all World Heritage forest site managers is resource limitation. Each site has a rela�tively limited budget that can be invested in manage�ment, M&A, and all the other demands placed on the site's budget. Investing in climatic and/or ecological monitoring represents one more demand on limited resources; setting priorities among those competing demands is a central function of management. There are at least two resources that would help an individual site manager evaluate climate change related risks compared to competing priorities: • Global models that evaluate relative climate change risk at World Heritage sites (i.e. Perry, 2011, Epple et al., 2010) identify sites perceived to be most at risk, and identify perceived causal factors (i.e. what makes one site more at risk than another). Sites generally perceived to be at higher risk will find monitoring an important investment. Variables perceived to drive vulnerability at a given site will often be useful components of a moni�toring programme. | Impacts | 25 - 25 |
| UNESCO | Adapting to Change (2011) | Summary Some World Heritage forest sites are at much higher risk of climate related changes than others. Recent attempts to assess relative climate change risk among World Heritage sites assist individual site managers in under�standing the magnitude of the risks they face, as well as the specific on-site variables most strongly driving such risk and therefore, most likely to change. Carefully designed and implemented ecological and climatic moni�toring programmes that actively engage a strong stake�holder base will be most effective in detecting and responding to climate induced changes. A proactive strategy will ensure the best decisions. Elements of such a strategy should include: 1) developing a World Heritage forest adaptation toolkit, 2) engaging the World Heritage forest community (i.e. managers and staff of the 104 designated forest sites) in an active discussion of antici�pated, climate induced changes, and 3) pairing sites to share analytical ideas and approaches. Actions such as those will increase the probability that climate change impacts are detected early and that proactive, adaptive strategies are identified and considered in a timely way. | Impacts | 25 - 25 |
| UNESCO | Adapting to Change (2011) | Nkem, J., C. Perez, H. Santoso, M. Idinoba. 2007. Methodological frame�work for vulnerability assessment of climate change impacts on forest based development sectors. CIFOR CATIE. | Impacts | 26 - 26 |
| UNESCO | Adapting to Change (2011) | http://www.cifor.cgiar.org/trofcca/attachment/03%20TroFCCA%20Annua l%20Report%20-%20%20Year%202%20-%20web.pdf Perry, J.A. 2011. A global model identifies the 16 natural heritage World Heritage sites most at risk from climate change. International Journal of Heritage Studies. In Press. | Impacts | 26 - 26 |

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| UNESCO | Adapting to Change (2011) | 3. Conservation Science Group, Department of Zoology, University of Cambridge, Downing Street, Cambridge CB2 3EJ, UK. WH WH WH One set of these relates to corridors of forest, such as riparian forests that are often preserved along river margins, and may connect a World Heritage forest to other forest areas. Corridors are known to promote the dispersal of species between habitat patches, thereby reducing biodiversity loss within them (Damschen et al., 2006). The likely efficacy of a corridor can be assessed using four criteria: (a) wide corridors are preferable to narrow corridors, as many species avoid forest edges and are therefore unlikely to move through a narrow strip of forest (Ewers and Didham, 2007); (b) shorter corridors are more likely to allow successful dispersal between patches than long corridors; (c) similarly, a corridor should ideally be continuously forested with no breaks, such as might be created by roads crossing the corridor (this is not to say that a 'broken' corridor will not function; as long as a species will cross small gaps then the individual patches of forest along that corridor can act as 'stepping stones', facilitating the movement of a species from one location to another); (d) finally, the size of the forest patch at the other end of the corridor is a strong determinant of the size of populations inhabiting that patch and therefore the likelihood of individuals leaving the patch to disperse along the corridor (Hanski, 1998). Corridors that connect a World Heritage forest to a large forest patch are likely to have a larger beneficial effect for the World Heritage forest than those connecting to a small forest patch. | Impacts | 27 - 28 |
| UNESCO | Adapting to Change (2011) | New developments in assessing connectivity Connectivity measures are being developed that better represent the impact of spatial patterns of forest on the dispersal of organisms, but this improvement comes at the expense of simplicity; measures are gradually increasing in complexity. The current approaches fall broadly into three groups based on metapopulation biology, graph theory and circuit theory respectively (Figure1). Perhaps the largest step forward in assessing connectivity has been to consider how a target patch is connected to all the forest patches in the landscape, rather than focusing on connec�tivity between individual pairs of fragments. Hanski (1998) presents a simplistic method for doing this that is widely used in metapopulation biology, based on three parame�ters: (a) the distance between the target patch and all other patches, with that distance weighted by, (b) the size of patches, and (c) the permeability of the matrix. | Impacts | 28 - 28 |
| UNESCO | Adapting to Change (2011) | References Cochrane, M. A. and W. F. Laurance. 2002. Fire as a large-scale edge effect in Amazonian forests. Journal of Tropical Ecology, Vol. 18, pp. 311–325. | Impacts | 29 - 29 |
| UNESCO | Adapting to Change (2011) | Ewers, R. M. and R. K. Didham. 2007. The effect of fragment shape and species' sensitivity to habitat edges on animal population size. | Impacts | 29 - 29 |
| UNESCO | Adapting to Change (2011) | E. Lee, P. Campbell, and C. Ondzeano. 2006. Impacts of roads and hunting on Central African rainforest mammals. Conservation Biology, Vol. 20, No. 4, pp. 1251–1261. | Impacts | 29 - 29 |
| UNESCO | Adapting to Change (2011) | Renjifo, L. M. 2001. Effect of natural and anthropogenic landscape matrices on the abundance of subandean bird species. Ecological Applications, Vol. 11, pp. 14–31. | Impacts | 29 - 29 |
| UNESCO | Adapting to Change (2011) | http://cmsdata.iucn.org/downloads/forests_1.pdf Adapting to changes 31 2 Introduction A shift from the traditional exclusionary conservation paradigm towards a more integrative landscape approach can be seen in the management philosophies of protected areas (PAs) (Phillips, 2003). This derives partly from a better scientific understanding of how humans have been shaping ecosystems and landscapes, increasing recognition of local and indigenous communities as well as uncertainties regarding the potential impacts of global climate change (Sayer and Maginnis, 2005). In addition, the frequent shortcomings in funding for PA manage�ment is an incentive for exploring new possibilities to monetize ecosystem services that are delivered by PAs (de la Harpe et al., 2004). In this regard, payment schemes for carbon sequestration services in the context of Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (REDD+), as currently negotiated under the United Nations Framework Convention on Climate Change (UNFCCC), might play a considerable role as an additional source of long-term funding for forest PAs in the future (Dudley, 2008; Harris et al., 2008). | Impacts | 29 - 30 |
| UNESCO | Adapting to Change (2011) | The present paper discusses general risks and benefits of REDD+ for biodiversity, and highlights recent developments and preliminary experiences regarding synergies between REDD+ and PAs, including World Heritage forest sites. | Impacts | 30 - 30 |
| UNESCO | Adapting to Change (2011) | Benefits and risks of REDD+ for biodiversity Additional benefits for biodiversity that can be derived from REDD+ include the conservation of forest biodiversity beyond the mere protection of forest cover, the establish�ment of corridors between PAs (see Chapter 4 on connec�tivity) (Wendland et al., 2009), the reduction of forest fire incidents (Stickler et al., 2009) and securing the sustain�able delivery of forest ecosystem services (UN-REDD, 2009). Furthermore, there are opportunities for enhancing biodiversity monitoring in and outside PAs. | Impacts | 30 - 30 |

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| UNESCO | Adapting to Change (2011) | Activities aimed at enhancing forest carbon stocks also bear such risks as they may encourage the establishment of monoculture plantations with low habitat and biodiver�sity value (Koh andWilcove, 2008; Danielsen et al., 2009). | Impacts | 30 - 30 |
| UNESCO | Adapting to Change (2011) | Furthermore, there is the risk of inter-ecosystem leakage since forest conservation under REDD+ can trigger a shift of land use conversion pressures to non-forest ecosystems with high biodiversity, such as peatlands or grasslands (Klink and Machado, 2005; Miles and Kapos, 2008; Paoli et al., 2010). PAs may also be threatened by leakage if REDD+ activities outside the PAs lead to an increase in deforestation pressure within the PAs. | Impacts | 30 - 30 |
| UNESCO | Adapting to Change (2011) | Notwithstanding these potential risks, REDD+ activities – if properly designed – can contribute to the long-term funding of PAs and to the conservation of biodiversity and ecosystem services in PAs within a landscape scale approach. World Heritage forest sites have Outstanding Universal Value (OUV) in terms of forest biodiversity and delivery of important ecosystem services (Ripley, 2007) and are therefore sites with high potential for achieving syner�gies between climate and biodiversity objectives under REDD+. The synergies between REDD+ and the long-term conservation of World Heritage forest sites are starting to be widely recognized, as demonstrated by the increasing 32 2 Adapting to Change – The State of Conservation of World Heritage Forests in 2011 REDD+ as a Contribution to Conservation and Connectivity of World Heritage Forest Sites by Steffen Entenmann and Christine B. Schmitt Institute for Landscape Management, University of Freiburg, Germany 1 1. University of Freiburg, Tennenbacher Strasse 4, D-79106 Freiburg. | Impacts | 30 - 30 |
| UNESCO | Adapting to Change (2011) | http://www.landespflege-freiburg.de/forschung/redd.en.html Contact details: steffen.entenmann@landespflege.uni-freiburg.de 2. Refer to Annex I, paragraph 2(e): http://unfccc.int/files/meetings/cop_16/application/pdf/cop16_lca.pdf 3. Refer to Annex A, paragraph 1(a): http://unfccc.int/files/meetings/work�shops/other_meetings/application/pdf/11cp7.pdf 4. Refer to Section III B, paragraph 70: http://unfccc.int/files/meetings/cop_16/application/pdf/cop16_lca.pdf<br>number of REDD+ related activities and pilot projects in and adjacent to World Heritage forest sites (Box 1). This development begs the question of how the impacts of REDD+ on World Heritage forest sites can be monitored (Phelps and Webb, this volume) and if REDD+ can contribute to the ecological connectivity of these sites. | Impacts | 30 - 31 |
| UNESCO | Adapting to Change (2011) | Valuing and monitoring biodiversity benefits in REDD+ pilot activities A growing number of REDD+ pilot projects worldwide have generated a wealth of experience in monitoring the impacts of REDD+ on forest biodiversity. Selling carbon certificates on the voluntary market is an important source of funding for these projects, and higher revenues can be expected if the project is certified for its positive biodiver�sity impacts by a third party based on recognized certifica�tion schemes (EcoSecurities, 2010). For instance, besides pure carbon certification, the CCBA Standard5 or the Plan Vivo Standard6 also evaluate socioeconomic and ecological impacts of carbon projects, and are valuable sources on how to assess and monitor forest biodiversity. | Impacts | 31 - 31 |
| UNESCO | Adapting to Change (2011) | In compliance with the mentioned standards, the state of biodiversity in REDD+ pilot projects is often described by the presence or abundance of particular (i.e. endemic or threatened) plant and animal species, and the number, extent and uniqueness of different forest habitats, forest structure, area, proportion of forest cover in the project area and degree of forest fragmentation. An assessment of the pre-project condition of biodiversity is thus the basis for subsequent monitoring activities, and for evaluating if the project generates any positive impacts on biodiversity. | Impacts | 31 - 31 |
| UNESCO | Adapting to Change (2011) | An important conceptual framework applied by many certification schemes for assessing forest biodiversity is the High Conservation Value (HCV) concept developed by the Forest Stewardship Council (FSC). This concept recognizes six types of HCV forests and provides guidelines for moni�toring the ecological conditions and changes in forests. It also recognizes whether the project area provides habitats to species listed on the IUCN Red List of Threatened Species, as well as important ecosystem services such as the provision and storage of water and the protection of soil against erosion. | Impacts | 31 - 31 |
| UNESCO | Adapting to Change (2011) | REDD+ is a new concept and there are few experiences regarding the impact of REDD+ activities on connectivity. | Impacts | 32 - 32 |
| UNESCO | Adapting to Change (2011) | Source: USGS & WWF 2006; IUCN & UNEP 2009; Regional Government Madre de Dios<br>It is important to point out that many serious problems exist in the region that are likely to reduce the positive effect of REDD+ activities on connectivity. It is expected that the recently completed Interoceanic Highway passing through the department of Madre de Dios will signifi�cantly reduce the possibility for many species to migrate, which cannot be offset by any REDD+ activity. The same holds true for the impacts of mining on the water quality of the rivers in the area, which also have an important function regarding landscape connectivity. | Impacts | 33 - 34 |

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| UNESCO | Adapting to Change (2011) | REDD+ activities can be an important contribution to reduce GHG emissions and improve conservation effec�tiveness in PAs of all IUCN management categories9. In PAs under IUCN categories I-IV, REDD+ measures can help in reducing illegal logging and increasing the conservation effectiveness, while in PAs under IUCN categories V-VI, REDD+ can help in reducing GHG emissions from legal forest management activities i.e. through sustainable forest management and the enhancement of carbon stocks; however, the biodiversity impacts of these activi�ties need to be carefully considered. | Impacts | 34 - 34 |
| UNESCO | Adapting to Change (2011) | REDD+ activities adjacent to World Heritage forest sites can have positive impacts on connectivity and conserva�tion effectiveness of World Heritage forest sites by protecting adjacent forest areas and by creating new forest habitat around the World Heritage forest sites through afforestation or reforestation activities (Bennet and Mulongoy, 2006). Regarding the creation of new forest habitat, Gardner et al. (2007) highlighted the controversy between studies stating that secondary forests provide a valuable habitat for species, suffering from primary forest loss (Wright and Muller-Landau 2006), and studies stating that forest quality is essential and more important than the size of the forest area. In particular, structurally poor secondary forests or plantations provide less suitable habitat for specialists and deliver less ecosystem services (citing Brook et al. 2006). | Impacts | 34 - 34 |
| UNESCO | Adapting to Change (2011) | 36 2 Adapting to Change – The State of Conservation of World Heritage Forests in 2011 9. For an explanation: http://www.unep-wcmc.org/protected_areas/categories/index.html<br>It is fair to assume that conservation or the creation of forest corridors, including secondary forests or structurally rich plantations adjacent to World Heritage forest sites, usually has positive impacts on ecological connectivity. | Impacts | 34 - 35 |
| UNESCO | Adapting to Change (2011) | We argue, however, that the effects of REDD+ projects on biodiversity and the connectivity and effectiveness of PAs, especially World Heritage forest sites, need to be systemat�ically evaluated. This is to some degree already done by existing standards, like those from FSC, CCBA or Plan Vivo. They include provisions for evaluating REDD+ activi�ties with regard to their suitability for serving as an ecolog�ical corridor between PAs to improve possibilities for species migration. The problem is that assessment of the functioning of ecological corridors requires sophisticated monitoring methods and indicators. In many cases (see case on the Kasigau Corridor REDD project) connectivity is assessed in terms of large mammal migration through degraded forest. In contrast, it is often not clear what the requirements of smaller animals or plants are regarding the ecological characteristics of corridors. | Impacts | 35 - 35 |
| UNESCO | Adapting to Change (2011) | Proximity to World Heritage forest sites could be taken into account when evaluating the effects on biodiversity of a REDD+ project as World Heritage forest sites per se have OUV and contain unique species and habitats. At least for the voluntary carbon market, where some buyers of carbon certificates are willing to pay a premium for carbon credits generated in projects with certified positive impacts of biodiversity, this might add value to the conservation effort and increase the price of the carbon credits. In order to keep track of the impacts on biodiversity of REDD+ in the World Heritage forest sites, objectives for biodiversity monitoring must be defined, and monitoring systems need to be established. This is automatically given if the REDD+ project takes place within the World Heritage forest site, but could also be required if it is located outside the World Heritage site, for example, the CCBA standard requires the assessment of off-site biodiversity impacts. | Impacts | 35 - 35 |
| UNESCO | Adapting to Change (2011) | Despite a reported overall decrease in threats to World Heritage forests in recent years, the 2001–2006 Threat Intensity Coefficients for a number of tropical sites demon�strate the potential for improved management and enforcement to reduce pressures from agricultural encroachment and deforestation (Patry and Ripley, 2007; Patry, 2007b). For World Heritage forests facing consider�able encroachment, engagement with REDD+ may depend on their ability to document these threats and the resulting/potential carbon losses. | Impacts | 37 - 37 |
| UNESCO | Adapting to Change (2011) | Safeguards and additional co-benefits REDD+ actions are generally expected to also deliver positive biodiversity and social outcomes. However, some REDD+ actions also have the potential for unintended negative consequences, such as the displacement of deforestation and degradation pressures into other areas of high biodiversity (Putz and Redford, 2009; Paoli et al., 2010). The Cancun Agreement adopted compulsory, if rudimentary, biodiversity and social safeguards for partic�ipating countries aimed at reducing the potential for unintended consequences and to promote multiple bene�fits from REDD+ (UNFCCC Annex I, 2010). The opera�tionalization of safeguards, however, remains uncertain with specifics under review through the UNFCCC, the Convention on Biological Diversity (CBD) and among indi�vidual Parties. Related negotiations will likely prove contentious, involving decisions on the monitoring and reporting of safeguards and the development of related indicators, including for measuring the biodiversity impacts of REDD+ actions. | Impacts | 41 - 41 |

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| UNESCO | Adapting to Change (2011) | • The World Heritage Committee might engage with the  CBD effort to maximize the biodiversity conservation  outcomes of REDD+ interventions. It might contribute to  the development of indicators for measuring the biodi�versity impacts of REDD+ actions. The CBD is also  lobbying for a REDD+ mechanism that also prioritizes  co-benefits, and the Committee might consider whether  to take a similar advocacy position. | Impacts | 42 - 42 |
| UNESCO | Adapting to Change (2011) | • The World Heritage Committee may consider building  internal REDD+ capacity so that the Centre can serve as  a resource to its Members States and designated forest  managers. As individual World Heritage forests contem�plate engagement with REDD+ policies and carbon  markets, the World Heritage Centre may become  responsible not only for helping designated forests to  identify opportunities, but also its associated risks (envi�ronmental, financial, legal). Similarly, World Heritage  forest manages are likely to be involved in national  discussions about state UNFCCC submissions and  national REDD+ strategy design, and it is important  that they have the resources to make well informed  contributions. | Impacts | 42 - 42 |
| UNESCO | Adapting to Change (2011) | http://www.wri.org/publication/summary-of-developed-country-fast�start-climate-finance-pledges  Cadman, T., Maraseni, T. 2011. The governance of climate change:  Evaluating the governance quality and legitimacy of the United Nations  REDD-plus Programme. International Journal of Climate Change: Impacts  and Responses, Vol, 2, No. 3, pp. 103–12. | Impacts | 42 - 42 |
| UNESCO | Adapting to Change (2011) | http://www.moderncms.ecosystemmarketplace.com/repository/modernc  ms documents/SFCM.pdf  44  2 Adapting to Change – The State of Conservation of World Heritage Forests in 2011<br>Hurowitz, G. 2011, 16 Feb. Budget for rainforests puts Obama's $1 billion  pledge at risk. Grist. http://www.grist.org  James, A., Gaston, K.J., Balmford, A. 2001. Can we afford to conserve  biodiversity? Bioscience, Vol. 51, No, 1, pp. 43–52. | Impacts | 42 - 43 |
| UNESCO | Adapting to Change (2011) | From a socioeconomic perspective, the buffer area also  has a role to play. If the farms, forest companies and other  industries that are located within the buffer area provide  good jobs, they can reduce the number of unemployed or  disenfranchised residents who might otherwise turn to  illicit activities such as illegal logging or wildlife poaching  within the protected area. The presence of jobs and law  enforcement within the buffer area can also counter the  negative spillover effects that have been observed when  protected areas become off-limits for certain economic  activities that were previously allowed. | Impacts | 44 - 44 |
| UNESCO | Adapting to Change (2011) | Next, we examined the certification assessment reports for  each of these nine operations. Among other things, the  assessment report identifies areas of non-conformance –  areas where the candidate forestry operation is not in  compliance with FSC standards. When this happens, oper�ations are issued a Corrective Action Request, or 'CAR',  that clearly specifies the action that must be taken to  come into compliance with the standard. If the non�conformance is minor, the FSC certificate is awarded and  the operation is given time – typically one year – to imple�ment the CAR. If the infraction is severe, a major CAR is  issued and the FSC certificate is not awarded until CAR  implementation is verified.6  Though not a perfect proxy for impact, we believe that the  CARs issued to an operation do provide valuable insights  into the areas where certification has resulted in forest  management improvements. Because we were specifically  interested in the changes that RA/FSC-certified companies  made that might affect the adjacent World Heritage sites,  we looked for CARs that required operations to take  corrective actions that would:   • Improve High Conservation Value Forest (HCVF) assess�ment  • Conserve HCVFs   • Protect rare, threatened or endangered species or their  habitats  • Limit the movement of invasive species  • Prevent or contain forest fires  • Improve worker wages or working conditions  • Enhance the viability of local communities  In the sections that follow, we identify those World  Heritage sites with adjacent RA/FSC-certified forestry oper�ations, outline the current threats that these sites face, and  describe the ways that their certified neighbours might be  contributing to their effectiveness and integrity. | Impacts | 45 - 45 |
| UNESCO | Adapting to Change (2011) | Tembec's CARs required the assessment and management  of HCVF areas, and the creation of larger 'protected  reserve' areas. Practices within riparian zones were also  addressed, with one CAR requiring the creation of a 7-  metre machine-free zone along all water bodies, except  where required for stream crossings. Tembec was also  required to mitigate the damages associated with mineral  exploration roads in areas designated as HCVFs. | Impacts | 46 - 46 |
| UNESCO | Adapting to Change (2011) | A number of actions were required to ensure that workers  were operating safely on steep slopes, including, among  others, training on the risk rating system for steep slopes  and information on their right to refuse unsafe work  without discrimination. Finally, a CAR was issued that  required the implementation of the company's local  purchasing policy, and the identification of local employ�ment opportunities in the town of Creston. | Impacts | 46 - 46 |

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| UNESCO | Adapting to Change (2011) | Landscape Labelling – the explicit association of the label with a sustainably managed landscape – could allow local stakeholders to capitalize on World Heritage status. Thus landscapes that encompass World Heritage forests might be managed in such a way as to minimize impacts on the protected forests by, for example, encroachment, pollu�tion, invasive species, and so on. Remnant forest patches or other natural habitats might also be actively maintained within the landscape, thereby improving the quality of the landscape matrix for forest species, and thus extending the conservation benefits of the World Heritage forests into the surrounding landscape. Recognizing such management activities through the designation of a wider Landscape Label might provide one pathway by which these activities can continue to be incentivized and rewarded. | Impacts | 54 - 54 |
| UNESCO | Adapting to Change (2011) | The Strategic Plan for Biodiversity 2011–2020 The CBD's new Strategic Plan promotes the effective implementation of the Convention through a strategic approach that will inspire broad based action by all Parties and stakeholders in order to halt the loss of biodiversity and ensure that by 2020 ecosystems are resilient and continue to provide the essential services that are securing the planet's variety of life, and are contributing to human well-being and poverty eradication. As such, the plan is intended as the overarching framework on biodiversity, not only for the biodiversity related conventions, but also for the entire United Nations system. | Impacts | 57 - 57 |
| UNESCO | Adapting to Change (2011) | The new Strategic Plan builds on the analysis of past fail�ures to slow biodiversity loss. As highlighted in Figure 1, past action in support of biodiversity generally focused on addressing the direct pressures causing biodiversity loss, intervening directly to improve the state of biodiversity, for example in programmes to protect particular endangered species. The approach taken in the new Strategic Plan broadens the action to include addressing the underlying causes of indirect drivers of biodiversity loss (such as demographic change, consumption patterns or the impacts of increased trade), and protecting the benefits provided by ecosystems. | Impacts | 57 - 57 |
| UNESCO | Adapting to Change (2011) | At the heart of the Strategic Plan are twenty ambitious but realistic targets collectively known as the Aichi Biodiversity Targets. These targets must be met over the next decade if the plan is to be realized. The implementation of the Plan coincides with the International Decade of Biodiversity 2011–2020 announced by the UN General Assembly in December 2010. There are four targets that are directly relevant to forests and protected areas, including World Heritage sites. These 2020 targets include: • to at least halve, and where feasible bring close to zero, the rate of loss of all natural habitats, including forests, and to significantly reduce degradation and fragmenta�tion (Target 5); • to manage areas under agriculture, aquaculture and sustainably managed forests (Target 7); • to conserve at least 17 per cent of terrestrial and inland water and 10 per cent of coastal and marine areas (Target 11); and 60 3 Adapting to Change – The State of Conservation of World Heritage Forests in 2011 Forests and Protected Areas: Outcomes of the Tenth Meeting of the Conference of the Parties to the Convention on Biological Diversity by Johannes Stahl, Tim Christophersen and Jason Spensley Secretariat of the Convention on Biological Diversity, Montreal, Canada<br>• to enhance the resilience and the contribution of biodi�versity to carbon stocks through conservation and restoration, including restoration of at least 15 per cent of degraded ecosystems, thereby contributing to climate change mitigation and adaptation, and to combating desertification (Target 15). | Impacts | 57 - 58 |
| UNESCO | Adapting to Change (2011) | • Finally, decision X/33 on biodiversity and climate change contains several paragraphs related to reducing emis�sions from deforestation and forest degradation in developing countries (REDD-plus). The decision invites 62 3 Adapting to Change – The State of Conservation of World Heritage Forests in 2011 Not for food: Control of bushmeat harvesting is a key part of the CBD forest agenda. © CBD Secretariat 1. The full text of the Strategic Plan, including all the Aichi Biodiversity Targets, is available at: http://www.cbd.int/sp 2. The full texts of these decisions are available at: http://www.cbd.int/deci�sions<br>Parties and other governments to enhance the benefits for and avoid negative impacts on biodiversity from REDD-plus, and other sustainable land management and biodiversity conservation and sustainable use activities. It requests the Executive Secretary to provide advice on relevant REDD-plus safeguards for biodiversity, based on effective consultation with Parties and their views, and with the participation of indigenous and local communi�ties. It also requests the Executive Secretary to identify possible indicators that assess the contribution of REDD�plus towards achieving the objectives of the CBD, and to assess potential mechanisms that monitor the impacts of REDD-plus on biodiversity. | Impacts | 59 - 60 |

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| UNESCO | Adapting to Change (2011) | CBD LifeWeb Initiative The CBD LifeWeb Initiative facilitates financing for protected areas to conserve biodiversity, address climate change and secure livelihoods. Managed by the CBD Secretariat, LifeWeb was invited by the Conference of the Parties to the CBD in its decision IX/18(11–12), and was reinforced by decision X/31 in 2010. It provides value�added by: (i) serving as an electronic clearing house of funding priorities; (ii) supporting Parties to hold financing roundtable meetings to strengthen international coopera�tion based on national priorities for protected area systems; and (iii) recognizing financing for priorities conveyed through CBD LifeWeb. Since 2009, sixteen donor partners have provided over US$120 million in funding support for projects profiled through this clearing house. Much of this support has been for the conserva�tion and restoration of forest areas. Over thirty-five coun�tries are currently profiling further priorities, and partner�ships are being sought with support of CBD LifeWeb for an additional US$720 million. World Heritage Sites are of special relevance to CBD LifeWeb, particularly given their unique visibility and the need for good examples of ecosystem goods and services that can be derived from the effective management of protected areas.3 REDD-plus consultations In collaboration with partners, the Secretariat organizes a series of regional consultation and capacity-building workshops on REDD-plus, including on relevant biodiver�sity safeguards. The workshops aim to consult effectively with Parties on biodiversity aspects of REDD-plus. They develop advice on REDD-plus and relevant safeguards, on possible indicators to assess the contribution of REDD-plus to achieving the objectives of the CBD, and on potential mechanisms to monitor the impacts of REDD-plus on biodiversity. The workshops also contribute to capacity�building on REDD-plus. The results are intended to support both the CBD and the United Nations Framework Convention on Climate Change discussions on safeguards, as well as on the monitoring of biodiversity in the context of the forest related targets of the Strategic Plan. | Impacts | 61 - 61 |
| UNESCO | Adapting to Change (2011) | 66 3 Adapting to Change – The State of Conservation of World Heritage Forests in 2011 Category of forest user Cash income Non-cash income Total Forest income as a percentage of total income Wealthy and average men 42 58 100 Of which forest 7 31 38 Wealthy and average women 36 64 100 Of which forest 10 34 44 Poor and very poor men 38 62 100 Of which forest 9 36 45 Poor and very poor women 32 68 100 Of which forest 12 38 50 Average contribution of cash and non�cash income to total income 37 63 100 Average contribution of forest income to total income 9 35 44 Table 1. Forest use in the village of Tenkodogo, Burkina Faso (per cent)<br>The importance of World Heritage forests World Heritage forests could play a tremendous role in promoting the essential values of forests. With 104 protected forests now recognized as World Heritage prop�erties, the network of World Heritage forests brings together the world's most outstanding forests, many of which provide the greatest value in terms of beauty, but also biodiversity, carbon storage, erosion prevention, and of course social and cultural values, which after all lie at the core of the concept of the World Heritage Convention. | Impacts | 63 - 64 |
| UNESCO | Adapting to Change (2011) | The vision of human populations acting as key players in biodiversity conservation and sustainable use has been embedded in UNESCO's Man and the Biosphere (MAB) Programme since its launch in 1971. The issue of forests, infused with the notion of their ecological, economic and cultural values, has been addressed by the MAB Programme since its earliest days. From scientific projects, addressing the issues of ecological effects of increasing human activities on tropical and sub-tropical forest eco�systems, and ecological effects of different land uses and management practices on temperate and Mediterranean forest landscapes, the MAB Programme has gradually shifted its focus towards exploring how the improved protection and management of forested landscapes in and around specific sites, or biosphere reserves, could contribute to biodiversity conservation while improving social, economic and cultural well-being of resident human communities. | Impacts | 65 - 65 |
| UNESCO | Adapting to Change (2011) | It is interesting to note that forty out of one hundred and three World Heritage forests 2, thus more than one-third, constitute the legally protected core area of forest biosphere reserves, with eleven located in post-Seville sites (Table 1). In this context, and bearing in mind the alarming rate of forest destruction and degradation worldwide, there is a need to explore and document ways and means in which the dual World Heritage–Biosphere Reserve designation can increase the effectiveness of long-term conservation of World Heritage forests as well as fulfilling the overall conservation and development functions of biosphere reserves. | Impacts | 65 - 65 |

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| UNESCO | Adapting to Change (2011) | 69 3 Country Biosphere Reserve (year designated) WH Forest Site (year inscribed) Australia Great Sandy (2009)* Fraser Island (1992) Belarus Belovezhskaya Puscha (1993) Belovezhskaya Puscha / Bialowieza Forest (1979; extension: 1992) with Poland Brazil Pantanal (2000)* Pantanal Conservation Area (2000) Central Amazon (2001)* Central Amazon Conservation Complex (2003) Mata Atlantica, including Sao Paulo City Green Belt (1993; extension 2002)* Discovery Coast Atlantic Forest Reserve (199) Atlantic Forest Southeast Reserves (1999) Cerrado (1993; extension 2000 and 2001) Cerrado Protected Areas: Chapada dos Veadeiros and Emas National Parks (2001) Bulgaria Doupki-Djindjiritza (1977) Pirin National Park (1983) Cameroon Dja (1981) Dja Faunal Reserve (1987) Canada Waterton (1979) Waterton Glacier International Peace Park (1995) with USA China Jiuzhaigou Valley (1997)* Jiuzhaigou Valley Scenic and Historic Interest Area (1992) Gaoligong Mountain (2000)* Three Parallel Rivers of Yunnan Protected Areas (2003) Huanglong (2000)* Huanglong Scenic and Historic Interest Area (1992) Wuyishan (1987) Mount Wuyi (1999) Wolong Nature Reserve (1979) Sichuan Giant Panda Sanctuaries (2006) Costa Rica/Panama La Amistad (Costa Rica: 1982; Panama: 2000)* Talamanca Range-La Amistad Reserves- La Amistad National Park (1983) Côte d'Ivoire Tai (1977) Tai National Park (1982) Comoé (1983) Comoé National Park (1983) Côte d'Ivoire /Guinea Monts Nimba (1980) Mount Nimba Strict Nature Reserve (1981) Cuba Cuchillas del Toa (1987) Alejandro de Humboldt National Park (2001) Germany / Slovakia / Ukraine East Carpathians (1998)* Primeval Beech Forests of the Carpathians and the Ancient Beech Forests of Germany (2007; extension: 2011) Guatemala Maya (1990) Tikal National Park (1979) Honduras Río Plátano (1980) Río Plátano Biosphere Reserve (1982) India Sunderban (2001)* Sundarbans National Park (1987) Nanda Devi (2004)* Nanda Devi and Valley of Flowers National Parks (1988, 2005) Indonesia Gunung Leuser Biosphere Reserve (1981) Giam Siak Kecil-Bukit Batu Biosphere Tropical Rainforest Heritage of Sumatra (2004) Reserve (2009)* Japan Yakushima Island (1980) Yakushima (1983) Kenya Mount Kenya (1978) Mount Kenya National Park / Natural Forest (1997) Mexico Sian Ka'an (1986) Sian Ka'an (1987) Mariposa Monarca (2006)* Monarch Butterfly Biosphere Reserve (2008) Montenegro Tara River Basin (1976) Durmitor National Park (1980) Panama Darien (1983) Darien National Park (1981) Peru Manú (1977) Manú National Park (1987) Philippines Palawan (1990) Tubbataha Reef Marine Park (1993) Puerto-Princesa Subterranean River National Park (1999) Portugal Santana Madeira (2011)* Laurisilva of Madeira (1999) Poland Bialowieza (1976) Belovezhskaya Puscha / Bialowieza Forest (1979; extension: 1992) with Belarus Russian Federation Baikalskyi (1986) Lake Baikal (1996) Barguzinskyi (1986) Lake Baikal (1996) Sikhote Alin (1978) Central Sikhote-Alin (2001) Perchoro Ilychskiy (1984) Virgin Komi Forests (1995) Senegal Niokola-Koba (1981) Niokolo-Koba (1981) Sri Lanka Sinharaja (1978) Sinharaja Forest Reserve (1988) United States of America Glacier (1976) Waterton Glacier International Peace Park (1995) with Canada Southern Appalachian (1989) Great Smoky Mountains National Park (1983) Olympic (1976) Olympic National Park (1981) California Coast Ranges (1983) Redwood National and State Parks (1980) Yellowstone (1976) Yellowstone National Park (1978) Table 1. List of Biosphere Reserves (BR) which are wholly or partially World Heritage Forest sites *Post-Seville Biosphere Reserves<br>In general, although World Heritage forests are protected for their outstanding universal value, they are faced with the problem of ecological isolation as a result of deforesta�tion, or the conversion of surrounding forest ecosystems for pasture, agriculture or mining purposes. Apart from | Impacts | 66 - 67 |
| UNESCO | Adapting to Change (2011) | Case Studies i) Sierra Gorda Biosphere Reserve (Mexico) Biosphere reserves invite local communities and other stakeholders to design site and context-specific approaches to strengthen landscape level ecological connectivity that translates into the reduction of forest destruction and degradation. Through focused land use policies, such as creating biological corridors and planting trees around farms located in biosphere reserves, more forest cover is established at the landscape level, thus decreasing the ecological isolation of forest habitats. | Impacts | 67 - 67 |
| UNESCO | Adapting to Change (2011) | • Bia Biosphere Reserve, Ghana Ghana submitted a funding request to the UNESCO Participation Programme during the 2010–2011 funding period to carry out a climate change impact assessment study on the Bia Biosphere Reserve. The aim of this study is to obtain scientific knowledge on the cause and effect relationship of climate change on the biosphere 70 3 Adapting to Change – The State of Conservation of World Heritage Forests in 2011<br>reserve in order to develop sound mitigation and adap�tation measures for the ecosystem. Subsequently, these mitigation and adaptation options will be integrated into the biosphere reserve's current management plans. | Impacts | 67 - 68 |
| UNESCO | Adapting to Change (2011) | a forest species would be at risk if restricted to its relatively small territory. Similarly, under various climate change scenarios, the inability of some species to adapt their ranges to different temperature and rainfall regimes could also spell disaster. Under these circum�stances, the identification and development of suitable ecological corridors becomes very important. | Impacts | 71 - 71 |
| UNESCO | Adapting to Change (2011) | According to FAO (2011), Central America shows the largest percentage loss of forest area globally, with an annual change rate of 1.19 per cent between 2000 and 2010. Figure 2 illustrates cumulative forest fires in the region between 2005 and 20094; these fires frequently correspond to forest clearing for agriculture and cattle ranching. | Impacts | 77 - 77 |

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| UNESCO | Adapting to Change (2011) | While migrating populations and land use change for  subsistence, small scale farming and cattle production  remain part of the challenge (contributing to 13 per cent  of forest loss in tropical Latin American Countries in the  period 1990–2000), today there is significant deforestation through large scale agriculture (47 per cent in the same  period) attributed mainly to monoculture crops (pineapple,  palm oil, citrus fruits). New threats are on the horizon  related to the production of biofuels. In addition, drug  related land use change has also recently become an  important issue with money laundering feeding forest  clearing for cattle ranching, especially in Guatemala and  Honduras, further complicating matters. | Impacts | 77 - 77 |
| UNESCO | Adapting to Change (2011) | Case Studies – On Connectivity   81  4  Figure 1. Mesoamerican Biological Corridor  4. http://maps.geog.umd.edu/website/Activefire_HTML/viewer.htm?MAP=  C_America-ArcIMSparam&DATALIST=,CO,mafd09,ER,&BANNER=CAM_banner&ele_fire=fireAims&requiredMap=CentralAmerica<br>Climate change is a rapidly growing threat that is already  affecting the region. In 2007, hurricane Felix destroyed  973,000 ha of forest in Bosawas (GTZ and MASRENACE,  2010). In the national parks of Monteverde and  Guanacaste in Costa Rica, worrying ecological shifts in  the cloud forests are being observed as cloud formation  is rising above the habitual altitudes, exposing the forests  to increased cloudless days, which appear to contribute  to forest die-offs, increasingly observed in recent years in  both areas (Research coordinators, personal communica�tion, 2010). Current projections (Anderson et al., 2008)  for the region are not very positive with stronger impacts  to be expected within the next decade (Figure 3). The region is actually being cataloged as one of the ‘Climate  change hotspots’ (Giorgi, 2006). Already in the 2020s,  significant changes in precipitation and temperature are  projected to push ecosystems outside of their comfort  zone in many areas (Research coordinators, personal  communication, 2010). | Impacts | 77 - 78 |
| UNESCO | Adapting to Change (2011) | 82  4 Adapting to Change – The State of Conservation of World Heritage Forests in 2011  Figure 2. A map of cumulative forest fires in the region between 2005 and 2009<br>Case Studies – On Connectivity   83  4  Figure 3. Climate change and biodiversity hotspots in Mesoamerica  Source: Anderson, E.R., Cherrington, E.A., Flores, A.I., Perez, J.B., Carrillo R., and E. Sempris. (2008) Potential impacts of climate change  on biodiversity in Central America, Mexico and the Dominican Republic. CATHALAC/USAID. Panama City, Panama, p.105.<br>Payment for Ecosystem Services  The Payment for Environmental (ecosystem) Services (PES)  is a promising tool for forest conservation. Two decades  ago Costa Rica developed an innovative approach by  establishing a fuel tax of 3.5 per cent that goes into  paying forest owners a fee for the conservation of  standing forests, regeneration areas and forest planta�tions. Four environmental services were recognized in the  Biodiversity Law of 1996: biodiversity, water, carbon and  landscape. This has allowed the country to actually double  its forest cover over the last two decades, having now  over 50 per cent of the country under forest, significantly  contributing to re-establishing or maintaining ecological  connectivity between protected area nodes. | Impacts | 78 - 80 |
| UNESCO | Adapting to Change (2011) | References  Anderson, E.R., Cherrington, E.A., Flores, A.I., Perez, J.B., Carrillo R.,  and E. Sempris. 2008. Potential impacts of climate change on biodiversity  in Central America, Mexico and the Dominican Republic. CATHALAC/USAID,  Panama City, 105 p. | Impacts | 81 - 81 |
| UNESCO | Adapting to Change (2011) | Moreover, governance, based on secular knowledge and  ruled with pre-defined ancestral laws, respected land  tenure that was adapted to their way of life (Diaw, 1997;  Diaw and Njomkap, 1998). Nevertheless, the pressure  exerted on the DFR was real, as were measures currently  implemented to mitigate anthropogenic effects. | Impacts | 83 - 83 |
| UNESCO | Adapting to Change (2011) | Limitations of established partnerships  In practice, all these partnerships have limitations to the  mobilization of resources capable of supporting the efforts  necessary to apply the principles of sustainable develop�ment at a larger scale that encompasses the entire DFR  landscape. The low participation and awareness of local  communities in terms of the World Heritage forest  concept, and the absence of information on the Dja  Forum, which was implemented with the help of IUCN�Central Africa (BRAC) in the 1990s, have contributed to  these shortcomings. The impact of these processes on  community dialogue established by the ‘Model Forest  Partnership’ is thus still limited. In particular, the issues of  biodiversity conservation have yet to be fully appreciated  by local and indigenous populations. Nevertheless, they  are well aware of the current threat to a number of animal  and plant species, for example, the overexploitation of  Moabi tree (Baillonnella Toxisperma) for economic reasons. | Impacts | 84 - 84 |

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| UNESCO | Adapting to Change (2011) | Another challenge is the absence of an environmental education curriculum. The impact of the 'Model Forest Partnership' is also limited by the fact that stakeholders do not have the necessary jurisdiction or mandate that would allow them to apply their ideas directly in the field, and which would allow them the opportunity to engage in biodiversity conservation. The notable lack of dialogue among certain local stakeholders is a direct consequence of insufficient consultation and inadequate institutional�ization of a co-management system. Every one of the stakeholders has their own management plan for bio�diversity in the same area. This is the case of Geovic, a mining company exploiting cobalt and nickel ores close to the reserve. | Impacts | 84 - 84 |
| UNESCO | Adapting to Change (2011) | Citing the term employed by Klein in 1991 (cited by Bourque, 2008), a Model Forest partnership built around these stakeholders is a form of new social contract estab�lished at the local level. However, there is an urgent need to implement and reinforce the institutional bodies outlined in the Decree No. 1052/MINFOF 17 December 2007 that approved and executed the development plan for the DFR so as to ensure a stronger participation of the local population, particularly the Bakas whose survival depends directly on the forest. The Bakas fully understand the biology of animals, their reproductive cycle, their feeding habits and their migratory movements across the landscape, and are thus one of the key partners for the sustainable management of the entire DFR. The FOMOD incorporates their thoughts and positions on such current issues as forestry governance, the REDD, and anthro�pogenic climate change. As regards local economic issues, FOMOD's partners participate in discussions on the mitiga�tion of negative impacts as a result of forest exploitation and the mining of cobalt, nickel and iron. Furthermore, stimulating the local economy remains one of FOMOD's priorities so as to find a solution to the endemic poverty visible around the protected areas (Dja Faunal Reserve and Nki National Park). | Impacts | 85 - 85 |
| UNESCO | Adapting to Change (2011) | Conflicts that used to typify the relationships between the different stakeholders are now being replaced by an increasingly institutionalized collaboration. However, there are risks and traps inherent in the consultation and part�nership process (Bourque, 2008); while conflicts between groups may wane or diminish, others may appear as new issues are brought to the fore, occurring occasionally within the same group of stakeholders or Model Forest. | Impacts | 85 - 85 |
| UNESCO | Adapting to Change (2011) | This will raise greater awareness of the national and inter�national importance of biodiversity and thus help mitigate impacts as a result of the different anthropogenic activi�ties. This approach will rely on synergies in the action plans already implemented within the Model Forest frame�work, and will be reinforced by awareness-raising activities for the benefit of the populations. | Impacts | 85 - 85 |
| UNESCO | Adapting to Change (2011) | 90 4 Adapting to Change – The State of Conservation of World Heritage Forests in 2011<br>Introduction Latin America is covered by 22 per cent of the world's forest area. However, the condition of these forests is rapidly changing. Between 1990 and 2005, it experienced a 7 per cent decrease in area (64 million ha) principally as a consequence of the expansion of large-scale agriculture and cattle farming (FAO, 2009). Despite a significant increase in protected areas between 1990 and 2007 in the region, from 213 to 451 million ha, it is unlikely – espe�cially in South America – that the rate of deforestation will decrease (FAO, 2009). Add to that the change dynamic due to agricultural activities, tropical forests – in particular tropical dry forests – are at risk from the development of road infrastructure and the effects of climate change. | Impacts | 86 - 87 |
| UNESCO | Adapting to Change (2011) | Chiquitano Dry Forest: characteristics and threats Tropical dry forests constitute complex and fragile ecosys�tems, which are still little understood in terms of their biodiversity and ecological functioning (Sánchez-Azofeifa et al., 2005). Around 97 per cent of the remainder of these forests – at a global level – find themselves at risk as a consequence of various threats such as global climate change, fragmentation, fire, and conversion of lands to agricultural and cattle farming uses (Miles et al., 2006). | Impacts | 87 - 87 |
| UNESCO | Adapting to Change (2011) | During the glacial and interglacial periods, this forest advanced and retreated in successive episodes, serving as an ample shock-absorber between the dry ecosystems to the south and the humid ecosystems to the north (Pennington et al., 2004). Taking into account current characteristics such as area, state of conservation and connectivity with other ecoregions, including water basins, it plays a key role in mitigating the negative effects of climate change on the continent. | Impacts | 87 - 87 |
| UNESCO | Adapting to Change (2011) | However, other threats are putting this value at risk: the expansion of mechanized agriculture for soy bean produc�tion, the increase in grazing lands for large-scale cattle farming, road infrastructure development, colonization (natives from western Bolivia and Mennonite communi�ties), the development of mining for iron ore, gold and rare earth minerals, the iron and steel industry, land tenancy insecurity, and the increase in fires (FCBC, 2010). | Impacts | 87 - 87 |

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|---|---|---|---|---|
| UNESCO | Adapting to Change (2011) | UNESCO Inscription Criteria: Cultural i. to represent a masterpiece of human creative genius; ii. to exhibit an important interchange of human values, over a span of time or within a cultural area of the world, on developments in architecture or technology, monumental arts, town-planning or landscape design; iii. to bear a unique or at least exceptional testimony to a cultural tradition or to a civilization which is living or which has disappeared; iv. to be an outstanding example of a type of building, architectural or technological ensemble or landscape which illustrates (a) significant stage(s) in human history; v. to be an outstanding example of a traditional human settlement, land-use, or sea-use which is representa�tive of a culture (or cultures), or human interaction with the environment especially when it has become vulnerable under the impact of irreversible change; vi. to be directly or tangibly associated with events or living traditions, with ideas, or with beliefs, with artistic and literary works of outstanding universal significance. (The Committee considers that this crite�rion should preferably be used in conjunction with other criteria); Natural vii. to contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance; viii. to be outstanding examples representing major stages of earth's history, including the record of life, signifi�cant on-going geological processes in the develop�ment of landforms, or significant geomorphic or phys�iographic features; ix. to be outstanding examples representing significant on-going ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals; x. to contain the most important and significant natural habitats for in-situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation. | Impacts | 95 - 101 |
| UNESCO | Adapting to Change (2011) | 2. Tmp = Temperate, Tr = Tropical, Sbt = Subtropical<br>117 Published within the World Heritage Paper Series Managing Tourism at World Heritage Sites: a Practical Manual for World Heritage Site Managers Gestión del turismo en sitios del Patrimonio Mundial: Manual práctico para administradores de sitios del Patrimonio Mundial (In English) November 2002; (In Spanish) May 2005 Investing in World Heritage: Past Achievements, Future Ambitions (In English) December 2002 Periodic Report Africa Rapport périodique pour l'Afrique (In English and French) April 2003 Proceedings of the World Heritage Marine Biodiversity Workshop, Hanoi, Viet Nam. February 25–March 1, 2002 (In English) May 2003 Identification and Documentation of Modern Heritage (In English with two papers in French) June 2003 World Heritage Cultural Landscapes 1992-2002 (In English) July 2004 Cultural Landscapes: the Challenges of Conservation Proceedings from the Ferrara workshop, November 2002 (In English with conclusions and recommendations in French) August 2004 Mobilizing Young People for World Heritage Proceedings from the Treviso workshop, November 2002 Mobiliser les jeunes pour le patrimoine mondial Rapport de l'atelier de Trévise, novembre 2002 (In English and French) September 2003 World Heritage manuals1 World Heritage papers 2 World Heritage reports3 World Heritage papers 4 World Heritage papers 5 World Heritage papers 6 World Heritage papers 7 World Heritage papers 8<br>118 Partnerships for World Heritage Cities - Culture as a Vector for Sustainable Urban Development. Proceedings from the Urbino workshop, November 2002 (In English and French) August 2004 Monitoring World Heritage Proceedings from the Vicenza workshop, November 2002 (In English) September 2004 Periodic Report and Regional Programme - Arab States 2000-2003 Rapports périodiques et programme régional - Etats Arabes 2000-2003 (In English and French) June 2004 The State of World Heritage in the Asia-Pacific Region 2003 L'état du patrimoine mondial dans la région Asie-Pacifique 2003 (In English) October 2004; (In French) July 2005 Linking Universal and Local Values: Managing a Sustainable Future for World Heritage L'union des valeurs universelles et locales : La gestion d'un avenir durable pour le patrimoine mondial (In English with the introduction, four papers and the conclusions and recommendations in French) October 2004 Archéologie de la Caraïbe et Convention du patrimoine mondial Caribbean Archaeology and World Heritage Convention Arqueología del Caribe y Convención del Patrimonio Mundial (In French, English and Spanish) July 2005 Caribbean Wooden Treasures Proceedings of the Thematic Expert Meeting on Wooden Urban Heritage in the Caribbean Region 4–7 February 2003, Georgetown - Guyana (In English) October 2005 World Heritage at the Vth IUCN World Parks Congress Durban (South Africa), 8–17 September 2003 (In English) December 2005 Promouvoir et préserver le patrimoine congolais Lier diversité biologique et culturelle Promoting and Preserving Congolese Heritage Linking biological and cultural diversity (In French and English) December 2005 World Heritage papers 9 World Heritage papers10 World Heritage reports11 World Heritage reports12 World Heritage papers13 World Heritage papers14 World Heritage papers15 World Herit age reports16 World Heritage reports17<br>119 Periodic Report 2004 – Latin America and the Caribbean Rapport périodique 2004 – Amérique Latine et les Caraïbes Informe Periodico 2004 – América Latina y el Caribe (In English, French and Spanish) March 2006 Fortificaciones Americanas y la Convención del Patrimonio Mundial | Impacts | 110 - 115 |

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| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Authors: Jim Perry, Department of Fisheries, Wildlife and Conservation Biology, University of Minnesota Charlie Falzon, Welsh Institute for Natural Resources, University of Bangor, Wales Supervision, editing and coordination: Marc Patry, UNESCO World Heritage Centre Susanna Kari, UNESCO World Heritage Centre Technical support – field testing: Bandiougou Diawara, UNESCO World Heritage Centre Elsa Loubet, UNESCO World Heritage Centre Copyediting and proofreading: Caroline Lawrence Coordination of the World Heritage Paper Series: Vesna Vujicic-Lugassy, UNESCO World Heritage Centre Cover photo: Area de Conservación Guanacaste in Costa Rica is one of the World Heritage sites where the impacts of climate change on biodiversity loss are already visible. © OUR PLACE Graphic design: UNESCO/MSS / CLD/D Original layout: Recto Verso Composed and printed in the workshops of UNESCO The printer is certified Imprim'Vert®, the French printing industry's environmental initiative. | Impacts | 3 - 3 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | World Heritage Paper Series N°37: http://whc.unesco.org/en/series/ Table of Contents Foreword.............................................................................................................................................................. 5 Preface.............................................................................................................................................................. 6 Acknowledgements.............................................................................................................................................. 7 Using the guide.............................................................................................................................................9 1.1 The purpose of this guide ..........................................................................................................................10 1.2 Developing a plan – some practical considerations...................................................................................10 1.3 How the guide is structured.........................................................................................................................12 1.4 Key terms – an explanation..........................................................................................................................13 1.5 A note on local and indigenous peoples...................................................................................................14 1.6 A note on gender ............................................................................................................................................15 2 Understanding the context.........................................................................................................................17 2.1 World Heritage ...............................................................................................................................................18 2.2 Climate change ...............................................................................................................................................18 2.3 Understanding the complexity of the problem ..........................................................................................19 3 Planning for adaptation.................................................................................................................................23 3.1 Assess your site (1) – understand its OUV..................................................................................................24 3.2 Assess your site (2) – understand its features and attributes; set objectives..........................................29 3.3 Assess your site (3) – understand its sensitivity and vulnerability.........................................................33 3.4 How resilient is your site? ...........................................................................................................................38 3.5 Assess your capacity to adapt......................................................................................................................39 3.6 Adaptation options ........................................................................................................................................44 3.7 Key issues in adaptation planning..............................................................................................................47 3.8 Analyse different climate change scenarios..............................................................................................49 3.9 Understand likely OUV responses – analyse the risks...........................................................................53 3.10 Select and prioritize your actions ...............................................................................................................55 3.11 Implement your plan .....................................................................................................................................57 3.12 Monitoring and evaluation..........................................................................................................................60 3.13 Monitoring weather and climate patterns and their | Impacts | 3 - 5 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Factoring climate change into management of the World Heritage properties has many other benefits. Conservation of heritage will also increase the resilience of human communities to the impacts of climate change, for example through ecosystem services that World Heritage sites provide. Many World Heritage sites serve as natural buffers against climatic impacts and other disasters, or play a major role in climate change mitigation by reducing climate-altering carbon dioxide emissions in the atmosphere. | Impacts | 5 - 5 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Kishore Rao Director UNESCO World Heritage Centre Foreword © UNESCO / Raheel Mohammad 6 The impact of climate change on World Heritage natural and cultural properties was brought to the attention of the 29th session of the World Heritage Committee in 2005 by a group of concerned organizations and individuals. | Impacts | 5 - 6 |

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| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | The Committee requested the UNESCO World Heritage Centre, in collaboration with its Advisory Bodies (ICCROM, ICOMOS and IUCN), interested States Parties and the petitioners who had drawn the attention of the Committee to this issue, to convene a broad working group of experts on the impact of climate change on World Heritage and prepare a strategy and report for dealing with the issue. These documents were endorsed by the Committee at its 30th session in July 2006. | Impacts | 6 - 6 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | The World Heritage Centre has since endeavoured to provide support to States Parties and site managers in tackling climate change threats, for example through field projects in Peru (Manú National Park) and Indonesia (Tropical Rainforest Heritage of Sumatra), as well as the publication of Climate Change and World Heritage – Report on predicting and managing impacts of climate change on World Heritage and Strategy to assist States Parties to implement appropriate management responses,1 the Policy Document on the Impacts of Climate Change on World Heritage Properties, 2 and the compendium of Case Studies on Climate Change and World Heritage.3 This Practical Guide is an additional output from the World Heritage Convention's secretariat. We hope that it will be a good resource tool for World Heritage site managers interested in understanding how to respond to climate change, along with the climate change publications mentioned above. | Impacts | 6 - 6 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | 1 UNESCO World Heritage Centre, 2007b, Climate Change and World Heritage – Report on predicting and managing the impacts of climate change on World Heritage and Strategy to assist States Parties to implement appropriate management responses. http://whc.unesco.org/en/activities/474<br>2 UNESCO World Heritage Centre, 2008, Policy Document on the Impacts of Climate Change on World Heritage Properties. | Impacts | 6 - 6 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Special thanks to the men and women in the field who provided crucial feedback on the first draft of the guide while testing it at their own World Heritage sites: Kenya India Mount Kenya National Park/Natural Forest Simon Gitau James Mathenge Chripine Ngesa C. F. A. Githiria Joseph Nzumbi Warden Chogoria Warden Kamweti Kenya Lake System in the Great Rift Valley Muteru Njauini Kathryn Combes Alice Bett John Wambua Rauni Munene James Kimaru Raphael Kimosop Amos Chege Hellen Jerotich Steve Araka Kenya Wildlife Service Headquarters James Njogu Chrispin Ngesa Keoladeo National Park Khayati Mathur Sudarshan Sharma Bhumesh Bhadouria Nanda Devi and Valley of Flowers National Parks B. K. Gangte Rajiv Dhiman Hem Chander Indian National Agencies S. D. Attri Jagdish Kishwan Vinay Bhargav Akash Verma B. S. Adhikari V. P. Uniyal S. Sathyakumar K. Sivakumar S. A. Hussain<br>9 Using the guide Phong Nha-Ke Bang National Park (Viet Nam). © OUR PLACE<br>10 Using the guide 1.1 The purpose of this guide This guide is intended primarily to: assist those responsible for the management of a natural World Heritage site to understand how climate change may affect those features of the site that contribute to its Outstanding Universal Value (OUV); offer a framework for putting site-level climate change effects into the management context; provide guidance on how to assess risk to the site's OUV; offer ideas for identifying and selecting options for responding and adapting to climate change. | Impacts | 7 - 9 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | A key challenge in producing this guide was to define its scope – many of the suggested activities may not be obviously linked to climate change, and it is for the manager to make those links where appropriate. However most, if not all, protected area and natural resource management challenges can be linked to climatic factors. For example, conflicts over natural resources such as land, food, shelter and water can usually be linked to stresses caused by drought, flooding, erosion or disease, which are generally climate-driven. Therefore we have interpreted climate change adaptation in this guide quite broadly. | Impacts | 9 - 9 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Be prepared to take some calculated risks and choose the best solutions in the context of what is known and understood. | Impacts | 9 - 9 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Strategies for getting to work Do not try to study problems 'to death'. Investing too much time and resources in excessive data collecting may result in damage to the OUV of a site due to lack of timely action. | Impacts | 10 - 10 |

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| Organisation | Document | Quotation Content | Codes | Page |
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| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | A logical approach While management planning is not necessarily a chronological process, it is important to work systematically, first by trying to understand likely future climate change scenarios and by understanding how the OUV of a site might be affected by such conditions – this will depend on assessing vulnerability of the features that contribute to its OUV, linked to the implications of a range of climate scenarios. Some features may be more vulnerable to certain climate change impacts than others. | Impacts | 10 - 10 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Assessing the vulnerability of a site's features against a set of climate scenarios will help the manager to assess the degree of risk of climate change impacts to those features and hence to the site's OUV. | Impacts | 10 - 10 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Island ecosystems are extremely vulnerable to many climate-induced impacts, such as sea level rise and extreme weather events, affecting the coastal and marine biodiversity. East Rennell, Rennell Island (Solomon Islands). © OUR PLACE<br>12 Using the guide 1.3 How the guide is structured This guide is structured to reflect the general approach and thinking processes that a site manager would normally follow. As you work through the guide, we remind you how far you have progressed by summarizing the learning points and 'signposting' the next stage, by periodically referring to the diagram shown below. However, there is no need to follow every step unless you think it necessary. | Impacts | 10 - 11 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Context – World Heritage, climate change Outstanding Universal Value Sensitivity, Vulnerability, Resilience Features and attributes Capacity to adapt Climate change scenarios Potential options Assessing risk Implementation logistics Prioritizing action Monitoring and evaluation Sample worksheets are included throughout the guide. | Impacts | 11 - 11 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Sensitivity Sensitivity refers to how easily the values of a site can be irreparably damaged. A sensitive site is one whose features and their attributes can easily be transformed by a wide number of factors. | Impacts | 12 - 12 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Resilience Resilience refers to the ability of a site to survive impact and recover functioning to its original or desired state after a disturbance. Often referred to as its 'elasticity'. | Impacts | 13 - 13 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Where a forest suffers damage through fire or drought, it will be resilient when it is capable of restoring itself (as measured using appropriate indicators) after a period of time. | Impacts | 13 - 13 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | 1.5 A note on local and indigenous peoples Climate change exacerbates existing inequalities. Indigenous peoples and marginalized populations are particularly exposed and vulnerable to climate change impacts due to their resource-based livelihoods and the location of their homelands in marginal environments. | Impacts | 13 - 13 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | 15 Using the guide 1.6 A note on gender Women are disproportionately affected by climate change impacts, such as droughts, floods and other extreme weather events, because of women's limited access to resources, restricted rights, limited mobility and lack of voice in decision-making. However, women also play an important role in supporting households and communities to mitigate and adapt to climate change. | Impacts | 13 - 14 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | When designing adaptation strategies, it is crucial that climate change responses are gender aware, ensuring that women and men have an equal voice in decision-making on climate change and equal access to the resources necessary to respond to its negative effects. | Impacts | 14 - 14 |

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| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | 2.2 Climate change The first World Climate Conference was held in 1979 because scientists had begun to notice the increase of carbon in the atmosphere caused by human activities which seemed to match with the global temperature increase. In 1988, the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) set up the Intergovernmental Panel on Climate Change (IPCC) to provide the world with a clear scientific view on the current state of knowledge in climate change and its potential environmental and socio-economic impacts. | Impacts | 16 - 16 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Organized two years after the release of the IPCC First Assessment Report, the United Nations Conference on Environment and Development in Rio de Janeiro in 1992 (the Earth Summit) resulted in the establishment of the UN Framework Convention on Climate Change (UNFCCC), in which nations agreed to explore further the causes and effects of global warming and how to limit and cope with its impacts. In 1995, the first Conference of the Parties (COP), Figure 1: Global and continental temperature change. Source: IPCC (2007) the framework for the climate change negotiations, was Context – World Heritage, climate change Sensitivity, Vulnerability, Resilience Features and attributes Capacity to adapt Outstanding Universal Value Climate change scenarios Potential options Assessing risk Implementation logistics Prioritizing action Monitoring and evaluation<br>19 Understanding the context 2 launched to strengthen the emission reduction provisions of the Convention. Two years later in 1997, the Kyoto Protocol was adopted which legally binds the developed countries to reduce carbon emissions. Since then, the Conference of the Parties (COP) has resulted in further provisions, but many of these are non-binding, and the climate change challenge remains. | Impacts | 16 - 17 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | In 2007 the IPCC presented its Fourth Assessment Report.8 The report confirms that climate change is occurring now, mostly as a result of human activities (Figure 1). It illustrates the impacts of global warming already under way and to be expected in future, and describes the potential for adaptation of society to reduce its vulnerability. It also presents an analysis of costs, policies and technologies intended to limit the extent of future changes in the climate system. Some of this information has already been summarized in the previous climate change publications of the World Heritage Centre (see preface). The IPCC Fifth Assessment report will be completed in 2014. | Impacts | 17 - 17 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Climate change poses a major challenge to managers of protected areas. Its effects are ever-present and complicated, adding to stresses such as pollution, land-use change and habitat fragmentation. Mitigating and adapting to the 8 IPCC, 2007, Fourth Assessment Report: Climate Change 2007. | Impacts | 17 - 17 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | http://www.ipcc.ch/publications_and_data/publications_and_data_reports.shtml impacts of climate change, through policies and on-site practices, is subject to extensive research. More than 4,000 scientific papers about climate change have been published to date, more than half of them in the last two or three years. | Impacts | 17 - 17 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Nonetheless, climate change is not a passing trend – it is here to stay, and it will impact all landscapes, including all natural World Heritage sites, fundamentally changing the way we understand and manage them. We are witnessing unpredictable weather patterns, floods, unseasonal drought, fires, extreme heat and cold, storms and sea level rise, glacial melting and altered movements in wildlife. | Impacts | 17 - 17 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | More information on climate change science is available on the websites of the IPCC9 and the UNFCCC.10 9 http://www.ipcc.ch 10 http://unfccc.int/ 2.3 Understanding the complexity of the problem Before a site manager can begin to address the impacts of climate change, the complex nature of the problem needs to be appreciated. Such complexities are often resistant to easy resolution, and any attempt to solve one part of a problem may lead to new difficulties. | Impacts | 17 - 17 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | http://cognexus.org/wpf/wickedproblems.pdf 1) The traditional approach – identify the problem and then seek the solution – does not apply. Trying to understand the problem and then arriving at the solution may be impossible because different groups may see problems and solutions in different ways, and because there may be many unanticipated side effects resulting from different solutions. It is vital that in considering solutions, the natural World Heritage site manager critically analyses the possible ecosystem responses.<br>20 2 Understanding the context 2) There is no stopping point. All solutions are ‘interim’, and are driven by limits on political commitment, money, current understanding, human resources, time and energy. Managers must continually monitor the implications to their management interventions so that they can further improve or adapt them to changing environmental, social, economic or political realities. | Impacts | 17 - 18 |

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| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Solutions may need to be adjusted in the light of effects on the ecosystem and in response to opportunities, resources, acceptability and so on. | Impacts | 18 - 18 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | 5) Many solutions risk being expensive trials by error. All attempts at management on the ecosystem scale are expensive, complex and prone to some degree of failure, and it may be impossible to go back and try again, because the underlying conditions such as temperature or precipitation patterns are also changing. | Impacts | 18 - 18 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Problems caused by climate change are particularly challenging because they can manifest themselves in highly complex ways, not simply by direct effects. As a simple example, responses such as the conversion of land from food to biofuels or major renewable energy projects can result in a reduction in available land for cereals or crops, and cause a rise in prices for those commodities, which can then become unaffordable for many living in poverty. This could result either in an increase in the number of people seeking to occupy new land for subsistence, or in government policies that aim to clear forest land to release it for food production, thus losing timber for construction, fuel and food, which might lead to encroachment on protected lands including World Heritage sites. Thus a policy decision, made perhaps in a distant part of the globe, can lead to difficulties at the doorstep of the site manager. | Impacts | 18 - 18 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | State A experiences reduced grain harvest due to impacts of climate change Direct and indirect impacts on World Heritage sites in states B and C State A keeps all its cereals and crops for home consumption Signiffcant rises in world market prices of cereals and crops Migration of urban and rural poor seeking land for subsistence Encroachment and illegal hunting in protected areas Social and environmental pressures result in pollution of watercourses, loss of natural resources, soil erosion, etc. | Impacts | 18 - 18 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | State B responds by selling its cereals on the world market, at prices unaffordable to its poorer citizens State C responds by converting land from forests to food production, resulting in a signiffcant loss of forest<br>21 Understanding the context 2 In this example, simply enforcing regulations may address the immediate problem, but will not address its underlying causes and may not be a sustainable or equitable option. | Impacts | 18 - 19 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | The task is to think creatively:12 think beyond the spatial boundary of the site; think beyond the short term, and keep rethinking in the light of new information; think about problems at different levels, and how solutions will impact on people and ecosystems. | Impacts | 19 - 19 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | The capacity of World Heritage site management to adapt to climate change is determined by a number of activities taking place in the surrounding landscape. All protected areas have a spatial relationship with their surroundings, and exist within their wider ecosystems. A range of activities and requirements beyond the site will have a profound impact on its viability. Therefore, successful adaptation depends on the capacity of site managers to reconcile these different demands. | Impacts | 19 - 19 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Approach all levels strategically, recognizing that working at lower levels is generally less expensive and provides quicker responses but may have more limited impact on protecting the OUV. Therefore, the most appropriate strategy is often to work simultaneously on both lower- and higher-level issues (Figure 5). | Impacts | 20 - 20 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Practical action can be taken to micro-manage the critical habitats, perhaps by reducing erosion, diverting water, shading out, cutting, removing invasive species and so on. However, such actions on their own will do little to reduce impacts from the surrounding community, such as encroachment, disturbance or pollution. These will require a different, more strategic approach. | Impacts | 20 - 20 |

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| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | © David Geldhof 3<br>24 3 Planning for adaptation 3.1 Assess your site (1) – understand its OUV World Heritage sites are inscribed on the World Heritage List if they are considered as having Outstanding Universal Value (Figure 6). As such, they meet one or more of the ten criteria, of which criteria vii, viii, ix and x apply to natural World Heritage sites (see Example 2): Criterion vii – 'contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance.' Criterion viii – 'be outstanding examples representing major stages of earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features.' Criterion ix – 'be outstanding examples representing significant on-going ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals.' Criterion x – 'contain the most important and significant natural habitats for in situ conservation of biological diversity, including those containing threatened species of Outstanding Universal Value from the point of view of science or conservation.' Outstanding Universal Value Sensitivity, Vulnerability, Resilience Features and attributes Capacity to adapt Context – World Heritage, climate change Climate change scenarios Potential options Assessing risk Implementation logistics Prioritizing action Monitoring and evaluation Outstanding Universal Value Meets Criteria Integrity and Authenticity Protection and Management Figure 6: Illustration of the three pillars of Outstanding Universal Value (OUV). | Impacts | 21 - 22 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Does the site suffer from the adverse effects of development, neglect or any other degrading process? | Impacts | 23 - 23 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | http://whc.unesco.org/en/activities/643/ Do you have control over the processes causing deterioration? Who does? Have adaptation strategies been identified and implemented? | Impacts | 23 - 23 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Answering these questions honestly is essential in evaluating if and how different measures might help you to adapt to climate change impacts. | Impacts | 23 - 23 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Integrity can be assessed in terms of wholeness and intactness of the natural and/or cultural heritage and its attributes (Example 3).<br>The conditions of integrity are whereby the property: a) includes all elements necessary to express its Outstanding Universal Value (OUV) b) is of adequate size to ensure the complete representation of the features and processes which convey the property's significance c) is not threatened by adverse effects of development and/or neglect Operational Guidelines (UNESCO World Heritage Centre, 2013, paras 87–95)<br>26 3 Planning for adaptation Example 3. Assessing the integrity of the Snowey Mountains System. | Impacts | 23 - 24 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Does the site suffer from the adverse effects of development, neglect or any other degrading process? | Impacts | 24 - 24 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Yes see comment A number of fires have occurred, which may have a local impact on vascular plants; although there is no encroachment, poaching in the less strictly protected zones has been problematic; overgrazing in some areas. | Impacts | 24 - 24 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Do you have control over the processes causing deterioration? | Impacts | 24 - 24 |

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| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Does the site suffer from the adverse effects of development, neglect or any other degrading process? | Impacts | 25 - 25 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Do you have control over the processes causing deterioration? | Impacts | 25 - 25 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | https://portals.iucn.org/library/efiles/documents/2008-036.pdf 18 http://whc.unesco.org/en/list/120 19 http://whc.unesco.org/en/list/154 20 http://whc.unesco.org/en/list/8<br>29 Planning for adaptation 3 3.2 Assess your site (2) – understand its features and attributes; set objectives While the OUV provides a framework, on its own it does not offer enough detail for monitoring and providing evidence of climate change or its effects. In order to set objectives for site management, it is necessary to: identify those features of a site that contribute to its OUV; carefully analyse the attributes for each feature, and assess the condition of each feature based on its measurable attributes. | Impacts | 26 - 27 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | A consistent approach to documenting, recording and reporting the attributes of your site's key features will provide the basis for future impact assessment, as well as the basis for designing and implementing adaptation strategies. | Impacts | 27 - 27 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Features and attributes Sensitivity, Vulnerability, Resilience Capacity to adapt Climate change scenarios Potential options Assessing risk Implementation logistics Prioritizing action Monitoring and evaluation Outstanding Universal Value Context – World Heritage, climate change This section offers a systematic approach to monitoring and analysing the effects of climate change, and is a standard approach to managing and monitoring the condition of habitats and species. | Impacts | 27 - 27 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Extent and distribution of each species Reproduction rates and processes Grazers/browsers – species and distribution Presence of competing vascular species – rates of encroachment and loss Precipitation, temperature Site feature 9 Attributes (for each endemic landbird) Cloudey Island petrel Population size – numbers of pairs – dispersal Breeding sites – location, number Breeding rates – how often, how many Predation rates – native and non-native predators Competitors – native and non-native competitors Death rates – ageing, accidental death, exposure to disease Frequency of storm events/wind conditions Temperature, precipitation Feeding – locations, food species, habitats The above attributes should be monitored because they provide the basis for evidence of any changes that may be linked to climate factors, and therefore how the OUV might be negatively impacted. The managing team needs to consider how to consistently measure these attributes and how to present the results, in order to assess the condition of each feature and whether it is declining, stable or improving. The Operational Guidelines recommend site managers to identify 'key indicators for measuring its state of conservation'. | Impacts | 29 - 29 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Worksheet 3: Features and attributes – objectives Features Attributes Objectives FEATURE A B C D FEATURE A B C D FEATURE A B C D 33 Planning for adaptation 3 3.3 Assess your site (3) – understand its sensitivity and vulnerability It is important to remember that your site may contribute significantly to mitigating the effects of climate change – tropical forests, salt marshes and mangroves, sea grasses and peat uplands store large quantities of carbon, and most of them also serve as refuges and pockets of biodiversity that retain metapopulations, and in some cases act as natural protective barriers to climate-related physical impacts and other effects such as diseases. Moreover, as World Heritage sites are usually the largest, and often among the best�conserved within a local or regional network of protected areas, they can act as a centre of species dispersal to smaller protected areas, contributing to biodiversity conservation throughout a broader landscape. In this way, your site can play an important climate change adaptation role for the larger protected areas network. | Impacts | 30 - 31 |

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| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Protected areas also serve as natural buffers against climate impacts and other disasters, providing space for floodwaters to disperse, stabilizing soil against landslides and blocking storm surges. It has been estimated that coastal wetlands in the United States provide US$23.2 billion a year in protection against flooding from hurricanes. | Impacts | 31 - 31 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Protected areas can keep natural resources healthy and productive so that they can withstand the impacts of climate change and continue to provide the food, clean water, shelter and income communities rely upon for survival. Thirty-three of the world's hundred largest cities derive their drinking water from catchments within forest�protected areas. | Impacts | 31 - 31 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Natural Solutions: Protected areas helping people cope with climate change (Dudley et al., 2010) Outstanding Universal Value Sensitivity, Vulnerability, Resilience Features and attributes Capacity to adapt Context – World Heritage, climate change Climate change scenarios Potential options Assessing risk Implementation logistics Prioritizing action Monitoring and evaluation Emerald Lake, Canadian Rocky Mountain Parks (Canada). © Maureen Flynn<br>34 3 Planning for adaptation boundaries may be too porous to maintain integrity in the face of encroachments of many kinds – extraction, pollution, settlements, poaching and so on. A site may be particularly sensitive if it is a rare or unique type of habitat, or if it is isolated from similar sites. In Section 3.4 we ask 'how resilient is your site?' A sensitive site may be the opposite of a resilient site, as demonstrated by the examples given. | Impacts | 31 - 32 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | For the purposes of this guide, vulnerability is seen as the level of risk of damage by a specific threat, or sets of threats. | Impacts | 32 - 32 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Some sites are generally robust, but might be vulnerable to specific threats such as flooding or fire, and some species might be vulnerable specifically to predation, disease or hunting. Our concern has to do with vulnerability to the effects of climate change, and a sensitive site might be particularly vulnerable to this particular threat. | Impacts | 32 - 32 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Climate change impacts rarely happen in isolation. It is not always easy to establish clear cause and effect relationships between climate change and visible changes at a World Heritage site. What may seem as a new alien species to address may in fact be closely linked to higher temperatures, facilitating the spread of that species, or the reproductive failures of a key species may be linked to a disease that thrives in more humid conditions. | Impacts | 32 - 32 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Some climate change impacts will be cumulative, where each effect may seem to be minimal, but taken together a number of apparently minor effects may be significant. | Impacts | 32 - 32 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Other effects could be 'threshold', whereby a habitat seems to sustain impacts up to a certain point before collapsing. | Impacts | 32 - 32 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Some of the effects may be 'upstream', originating from distant regions. For example, migratory species that feed or breed in your area may be under severe drought stress in another country, resulting in changes in species interaction at your site, and potentially reducing its OUV. | Impacts | 32 - 32 |

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| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Land losses beyond World Heritage sites reduce livelihood alternatives of rural populations, resulting in encroachment and poaching of key species. | Impacts | 33 - 33 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Increases in temperature extremes, precipitation or extraction lead to a loss of fragile and rare flora. | Impacts | 33 - 33 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Wetland Climate-induced crop loss results in intensification of farmland use, which in turn leads to erosion, pollution from fertilizers and increased pressure to drain wetlands for agricultural uses. | Impacts | 33 - 33 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Lake Pollution from upstream industrial, agricultural or housing development as a result of relocation, leads to eutrophication, species losses, changes in habitat. | Impacts | 33 - 33 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Tropical forest Policy changes in response to climate-induced resource needs lead to increases in extraction or land-use changes, with consequent losses of important tree species and habitats. | Impacts | 33 - 33 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Loss of fauna and flora through poaching by climate change refugees. | Impacts | 33 - 33 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Loss of soils as a result of erosive forces upstream. | Impacts | 33 - 33 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Mangrove Changes in water levels result in tidal effects, increased erosion and loss of mangrove. | Impacts | 33 - 33 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Shoreline Coastal inundation or erosion as a result of higher sea levels. | Impacts | 33 - 33 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | For specific examples of the effects of climate change on World Heritage sites, consult the UNESCO World Heritage Centre publication Case Studies on Climate Change and World Heritage. | Impacts | 33 - 33 |

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| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Any threat to populations or hydrology can result in ecological loss or erosion, or an increase in pest-borne diseases, thus losing some of the necessary OUV elements. | Impacts | 33 - 33 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Any loss of habitat or reduction in size that results in a lack of capacity to support representative communities or processes. | Impacts | 33 - 33 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Any loss of attributes such as prey species, migration routes or breeding grounds that reduces the condition of features and leads to their losses. | Impacts | 33 - 33 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Encroachment, land conversion, human migration, intensification of water use, diversion of catchments and erosion can all result in adverse effects and degrading processes. | Impacts | 33 - 33 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Lack of control over any of the above can result in changes to vegetation patterns, increases in fire incidents, drought or poaching, leading to a loss of features and ecosystem breakdown. | Impacts | 33 - 33 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Lack of corridors and buffer zones results in the inability of species to migrate and find new breeding and feeding grounds, and can result in loss of key species and ultimately a breakdown in habitat.<br>36 3 Planning for adaptation Example 8. Monitoring the attributes of the endemic Cloudey Island petrel. | Impacts | 33 - 34 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Death rates – ageing, accidental death, exposure to disease Possible losses due to accidental snagging in fishing equipment. | Impacts | 34 - 34 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Human-induced fires are having an impact on important flora. Two of the lakes were stocked with non�native fish about seventy years ago, which may pose a threat to the native species, although the trends are not known.<br>37 Planning for adaptation 3 In conclusion, climate change vulnerability indicates the extent to which changes in climatic conditions are likely to cause a negative impact to the site's OUV. This is determined by: off-site stresses (e.g. future climate projections, surrounding landscape scale influences); on-site conditions (e.g. current state of conservation of rare species); and adaptive capacity (e.g. ability of management to take action to prevent negative outcomes). | Impacts | 34 - 35 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Invasive alien species: World Heritage case study – Galápagos There is widespread agreement that invasive alien species represent the greatest single threat to the Galápagos National Park (GNP) ecosystem, causing a burden to native species. More than 1,300 alien non-native species have been reported, including feral pigs, goats, rats and pigeons. Staff from the Galápagos National Park and the Charles Darwin Foundation have successfully eradicated several alien species (such as pigs, goats, tilapia, donkeys) from some islands. Such projects require extensive advance planning, capacity-building, funding and political support. However, there are also risks and high costs associated with any large-scale ecosystem manipulation. | Impacts | 35 - 35 |

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| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | In one case, for example, all members of an endangered raptor species were captured and held in captivity while invasive rats were exterminated. Nevertheless, as a result of efforts to remove invasive alien species, the islands' ecosystem is now more resilient to climate change impacts. | Impacts | 35 - 35 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | A more resilient site will be less likely to suffer negative impacts to its OUV. Protected areas are ecologically resilient where they are: relatively undisturbed – meaning they are under low stress and better equipped to resist new threats; relatively large, giving them the ability to self-restore if smaller parts of the protected area have been damaged by disease, fire or other such factors; ecologically well connected to the broader landscape – genetic pools remain healthy from the unobstructed movement of species in and out; temporary extirpations of rare species can be overcome by immigration; and gradual shifts in community make-up can occur as temperature and moisture gradients shift; relatively stable – they are not subjected to rapid and dramatic anthropogenic changes. | Impacts | 36 - 36 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Resilience can be described as elasticity: it refers to the ability of a system to survive impact and recover functioning to its original or desired state after a disturbance. A resilient system can absorb shocks such as flood, drought or major fire, without any significant long-term disturbances to its functioning. | Impacts | 36 - 36 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Although surrounded by the 300 ha Praslin National Park, the site itself is just 19.5 ha, and is extremely vulnerable to fire and to the illegal taking of the coco de mer nut as well as to invasive species and upstream activities. It is currently too small to sustain its values, and requires interventions such as replanting to maintain its unique ecosystem components. The area is at risk from changes in seasonal patterns of rainfall, with torrential rains affecting breeding and feeding patterns and causing significant erosion. Periods of drought have also increased the risk of fire. | Impacts | 36 - 36 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Outstanding Universal Value Sensitivity, Vulnerability, Resilience Features and attributes Capacity to adapt Context – World Heritage, climate change Climate change scenarios Potential options Assessing risk Implementation logistics Prioritizing action Monitoring and evaluation Tajik National Park (Mountains of the Pamirs) (Tajikistan). © Nomination file<br>40 3 Planning for adaptation Management systems The questions in Worksheet 4, adapted from the resource manual on Preparing World Heritage Nominations, 24 relate to management systems, and should be helpful in assessing vulnerability to climate change linked to site management. | Impacts | 37 - 38 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Does the management system include an assessment of risk and how to respond to it? | Impacts | 38 - 38 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | General level of knowledge of the site Extensive Good Some knowledge Limited None General level of support for the site and its aims Negative Positive -5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5 Particular areas of concern (if any) or opportunities for engagement Lack of trust? Past problems? Open antagonism? Breakdown in communication? Disagreements over rights? Etc.<br>42 3 Planning for adaptation Legal and policy context The ability to manage any World Heritage site (and to adapt to climate change impacts) will depend on the legal and policy support given by government, especially in relation to legal and policy issues that may potentially impact on a site's integrity, as well as the documentation that establishes its legal status. Additionally, many countries also have national strategies, policies and other legislation on climate change of which the site management should be aware. | Impacts | 39 - 40 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Significant development How might this influence natural features such as water, atmosphere, waste, invasive species, erosion, human encroachment, etc.? | Impacts | 41 - 41 |

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| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | However, the following broad options will help to ensure that your site is as resilient as possible, and to reduce the negative effects of climate change as far as possible. Each manager and team will have to decide for themselves how feasible some of these options are for a given site, and should develop an inventory of strategic options and necessary actions linked to each option. | Impacts | 42 - 42 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Remove/control invasive species if physically and financially possible. Costs can be considerable, including human resources, capture equipment, vehicles and transport; sighting and monitoring equipment; training in taxonomy and veterinary skills; tracking, trapping and capture skills; cutting equipment; the use of chemicals and their effects; safety and maintenance; monitoring skills; and general awareness about methods of elimination. Even if it is logistically possible, there might not be the political or public support necessary for such a programme. | Impacts | 42 - 42 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Invasive alien species: Case of Mikania micrantha Mikania micrantha is a fast-growing creeper, commonly known as 'mile a minute weed'. Its native range is in the tropical and subtropical zones of central and South America, where its impact is relatively insignificant. However, it is capable of spreading rapidly and smothering even large trees, resulting in major impacts on natural forests, grasslands, plantations and agricultural systems. It is the main invasive plant in Chitwan National Park in Nepal where it poses a threat to the rare one-horned rhino, as it has the potential to destroy plant species on which the rhino is dependent, as well as habitats and species that are rare in their own right. | Impacts | 42 - 42 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Build alliances with NGOs, businesses and landowners. Work with them to raise awareness of climate change. Work with adjoining landowners to enhance positive management and minimize negative impacts – encourage the control of pesticides, herbicides and fertilizers, especially where your site is 'downstream' of such land; encourage the naturalization of waterways and their shorelines. | Impacts | 43 - 43 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Engaging local communities: Case of the Sundarbans The Sundarbans mangrove forest, one of the largest mangrove forests in the world (140,000 ha), lies in the delta of the Ganges, Brahmaputra and Meghna rivers on the Bay of Bengal in Bangladesh. The Sundarbans World Heritage site is intersected by a complex network of tidal waterways, mudflats and small islands of salt-tolerant mangrove forests, and presents an excellent example of ongoing ecological processes. Various NGOs are working with farming communities surrounding Sundarbans National Park to reduce the amount of fertilizer and pesticide entering watercourses, and to develop organic systems and manage rainwater more efficiently. It is hoped that such practices will help to retain soils and encourage the growth of mangrove, thus reducing the potential impact of storm events and sea surges. | Impacts | 43 - 43 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | http://www.indiawaterportal.org/; http://whc.unesco.org/en/ list/798 Expand the effective size of the site, by introducing a buffer zone if possible, in order to allow for movement and population growth. Encourage sustainable use/ alternative livelihoods with surrounding communities in the area, so as to minimize impacts on adjoining ecosystems. Where feasible, secure formal agreements for co-management of resources. | Impacts | 43 - 43 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Given that the site is also subject to coastal erosion, it is particularly important that clear, agreed national and local policies are harmonized and rigorously applied in order to protect its OUV in the context of the wider landscape. Various planning, coastal protection, agriculture, floodwater and access laws are used to regulate activities and to establish and enforce protective policies. | Impacts | 43 - 43 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Working beyond boundaries: Case of Peninsula Valdés The endangered southern right whales are central to the OUV of Peninsula Valdés World Heritage site in Argentina. These whales come to calve at the site, but spend a good part of the year elsewhere. Site managers assess the climate change risks to whales not only at the site but throughout its range and determine if there is anything that can be done to reduce the risks. | Impacts | 44 - 44 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | http://whc.unesco.org/en/list/937 Carry out interventions, such as planting, clearing and fire setting in order to manage the balance of habitats, optimize colonization and reduce the risk of climate-linked calamities. Such interventions may differ considerably in scale, and can be expensive if maintained. You may decide to expand the amount of critical habitat for refuge, breeding or feeding purposes; or you may decide to increase the patchwork of a range of habitats in a landscape, which provide for flexibility or offer nesting and feeding opportunities. You may also need to develop corridors or migratory 'stepping stones' within your site. This may be particularly appropriate where a critical species contributes to your site's OUV, and assist either its translocation, or the translocation of its prey species. | Impacts | 44 - 44 |

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| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Use fire as a technique in adjoining sites to prevent climate-induced uncontrollable fires that may impact your site. Work with landowners to carry out appropriate programmes of controlled burning. | Impacts | 44 - 44 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | For example, communities may resent a road diversion that has an impact on their settlement; truckers may be against increases in distance and therefore fuel costs; local politicians may not support a diversion that reduces access to their communities. | Impacts | 44 - 44 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | http://whc.unesco.org/en/list/340 Where off-site ecosystem disruptions have impaired your site's integrity, you may need to use 'hard engineering' to restore it. Examples include large bridges over motorways to assist migrations; coastal infrastructure to protect sensitive sites by preventing build-up of silts as a result of longshore drift; and diversion of watercourses to retain wetland integrity. Wherever possible, engage (or encourage strategic partners to engage) with forums that make decisions about infrastructure. Influence planners to consider the impacts of roads, reservoirs and coastal defences on the integrity of your site. Influence thinking on whether changes in infrastructure are necessary compared with other options; if so whether they are appropriately located and of the right scale; what materials are used and where they are sourced; the potential for enhancements such as wildlife corridors/ tunnels/bridges; fish ladders; seasonal regulations to optimize breeding, feeding and movement, and so on. | Impacts | 44 - 44 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | 3.7 Key issues in adaptation planning 1. Ensure that you take into account the dynamics of climate change when developing management plans. You will need to consider the possible effects of sea level rise, increased storm incidents, flood events, drought, glacial retreat, etc. These may include change in land cover, habitats and species; erosion and silting up; or changes in migration patterns. You may therefore need to plan for coastal realignment; diversion or blocking of watercourses; expansion or reshaping of your site; or relocation of any settlements away from threatened valleys or coasts. Your plan should demonstrate that you have thought about these things and considered a range of options. Do not produce plans as if there will be no changes to your site over the next decades. | Impacts | 45 - 45 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Rezoning the Great Barrier Reef In 2004 the Australian Government rezoned the Great Barrier Reef to increase protection to a range of species and resources. For example, the 'no take' areas were increased from 5 to 33 per cent, and 'no trawl' areas from 15 to 28 per cent of the park. One of the main reasons was the protection of the marine turtle, which had suffered from various impacts including fishing. Overall, the area that provided increased protection for the three marine turtle species from trawling rose from 30 to 70 per cent. | Impacts | 45 - 45 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | http://www.gbrmpa.gov.au/zoning-permits-and-plans/zoning<br>48 3 Planning for adaptation 2. Review the zoning system for your site. You may need to carry out interventions on parts of it, and allow for new patterns of movement and colonization by both humans and wildlife in and around the site. If applicable, review the management of visitors to reduce erosion, waste, disruption, litter and other impacts. | Impacts | 45 - 46 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | ca/~w3bio/bio464/lectures/lectures_assets/sustainability_ of_indigenous_hunting.pdf; T. Moore, 2010, http://www.culturalsurvival.org/ publications/cultural-survival-quarterly/peru/peru-people�parks-and-petroleum 3. Review the laws and regulations that may have an impact on the effectiveness of your management and ability to adapt. Consider how social and economic programmes are influencing decisions about land, water and energy use in the landscape within which your site is located.26 Finally, you need to bear in mind the following: Attempting to solve a problem for one feature of the site's OUV may create new problems for other features. It may therefore be useful to think in terms of so-called Limits of Acceptable Change (LAC).27 Some degree of change is always certain, and we should focus our management efforts where they will have the greatest impact on sustaining the OUV while mitigating the unwanted changes. Therefore, we need to calculate how much loss is acceptable within certain limits. Some changes (e.g. a 10 per cent reduction in the population of an umbrella species) may be acceptable 26 J. Ohl-Schacherer et al., 2007, The sustainability of subsistence hunting by Matsigenka native communities in Manu National Park, Peru, Conservation Biology, Vol. 21, No. 5, pp. 1174–85. | Impacts | 46 - 46 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | 28 J. A. Perry, 2011a, Literature review on climate change adaptation and natural World Heritage sites, prepared for UNESCO World Heritage Centre; J. A. Perry, 2011b, World Heritage hot spots: a global model identifies the 16 natural heritage properties on the World Heritage list most at risk from climate change, International Journal of Heritage Studies, Vol. 17, No. 5, pp. 426–41. | Impacts | 47 - 47 |

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| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Outstanding Universal Value Sensitivity, Vulnerability, Resilience Features and attributes Capacity to adapt Context – World Heritage, climate change Climate change scenarios Potential options Assessing risk Implementation logistics Prioritizing action Monitoring and evaluation<br>50 3 Planning for adaptation Climate predictions for a specific site should be seen as a way to develop a context, or as a way to understand how significant the issue might be. Although we do not have the capability to change future climatic conditions, being forewarned gives a context for scenario-building, which in turn allows possible responses to be planned. | Impacts | 47 - 48 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | While future climate conditions are very difficult to predict precisely, even rough predictions will help a manager to think about the ways in which the attributes of the OUV may be expected to respond to future climate conditions. This allows at least some form of risk analysis as the basis for designing an adaptation plan. Such a plan should provide a range of prioritized actions, both within and beyond the site itself. | Impacts | 48 - 48 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Before considering risk, we look at some scenarios at site level, and think about their possible effects. While climate futures are unpredictable, we can perhaps guess that some scenarios are less likely than others, so it would be useful to eliminate the least likely ones, and spend more time thinking about: scenarios that you can envisage will have a direct impact on your site; scenarios that might impact your region generally, and might therefore have a knock-on effect on your site. | Impacts | 48 - 48 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | A useful way to analyse this is to think 'what if ...'. For example, 'What if my site began to experience increases in sustained storms?' 'What if my site experienced drier summers?' The IPCC's Fourth Assessment Report29 (2007) predicted a number of global future scenarios with high degrees of certainty. Some of these are particularly relevant to our two theoretical sites, shown in Example 9. Any of these climate effects might result in a range of impacts that will undermine a site's OUV. | Impacts | 48 - 48 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | 29 http://www.ipcc.ch/publications_and_data/ar4/syr/en/contents.html Glaciers are melting worldwide and the appearance of some mountainous sites, sometimes inscribed because of their exceptional aesthetic beauty, could change dramatically. Tongariro National Park (New Zealand). © OUR PLACE<br>51 Planning for adaptation 3 Example 9. Possible climate change impacts at the Cloudey Island and the Snowey Mountains System sites. | Impacts | 48 - 49 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | 'Coasts will be exposed to increasing risks such as coastal erosion due to climate change and sea-level rise' 'Increases in sea-surface temperature of about 1–3 °C (will) result in more frequent coral bleaching events and widespread mortality unless there is thermal adaptation or acclimatization by corals' Increased exposure to higher turbulence from the sea Changes to marine biology Increased exposure of plateau scrub to salt spray Changes to reef pattern Increased exposure of beach to rising sea levels and turbulence Increase in tropical storm events Accelerated undermining of cliffs and caves Loss of prey species Loss of endemic invertebrates Coral bleaching Disruption to turtles nesting on the beach Loss of habitat and associated species 'More and larger glacial lakes' 'Increasing rock avalanches ...' 'Increased run-off and earlier spring peak discharge in many glacier and snow-fed rivers' 'Changes affecting algae ... fish and zooplankton because of rising water temperatures and changes in: ice cover, oxygen levels, water circulation' 'Dry regions will get drier, and wet regions will get wetter' 'Spring events such as the unfolding of leaves, laying of eggs and migration are happening earlier' '...pole-ward and upward (to higher altitude) shifts in ranges of plants and animal species' Shorter periods of freezing Increased avalanche events Wetter conditions in some areas Changes to lake biology, as a result of increased eutrophication Drier, hotter conditions in high plateau areas Changes in habitat – loss or migration of some plant communities Increased silting downstream Catastrophic flooding as a result of glacial dam bursts New lakes formed from avalanche debris Increases in algal blooms Disruption to feeding/ breeding habits of key mammal species Loss of feeding grounds/ refuge sites for migrating birds Migration of prey species Increases in uncontrolled fire events<br>52 3 Planning for adaptation Example 10. Problem tree analysis. | Impacts | 49 - 50 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | A useful way to analyse the effects of climate change on your site is to use a 'problem tree' to consider the potential effects of a problem. The Snowey Mountains System team analysed the ways that the structure of the plateau grassland habitat might change, shown below. | Impacts | 50 - 50 |

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| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Hotter, drier conditions on plateau Loss of plant cover Loss of pollinating insects Increased number of uncontrolled ffres Changes in habitat structure Exposure and erosion of soils Incapacity of ffora to recover Loss of critical ffora Out-migration of herbivores Loss of key predators Increased water run-off Downstream impacts Rough predictions such as the above will help a manager to think about the ways that the attributes of the OUV may be expected to respond to future climate conditions (i.e. a risk analysis). The risk analysis forms the basis for designing an adaptation plan, which should relate to a spatial hierarchy of actions, both within and beyond the site itself (see Section 3.10 on adaptive actions). | Impacts | 50 - 50 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (IPCC) http://www.ipcc-wg2.gov/SREX/images/uploads/SREX-All_ FINAL.pdf Pacific Climate Futures (Government of Australia) http://www.pacificclimatefutures.net/ USA Climate Futures (United States Government) http://epa.gov/climatechange/science/future.html Visualizing Future Climate in Latin America: Results from the application of the Earth Simulator (World Bank) http://siteresources.worldbank.org/INTLAC/Resources/ SDWP_Future_Climate.pdf PRECIS (Providing Regional Climates for Impacts Studies) Regional Climate Modeling System PRECIS, developed and maintained by the UK Hadley Centre, is the most widely used, fine-scale, user-driven climate modelling system currently available. It is also appropriate for local application at a natural World Heritage site. PRECIS is available free of charge, but its use requires attending a training workshop, which are organized worldwide. | Impacts | 50 - 50 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | http://www.metoffice.gov.uk/precis/<br>53 Planning for adaptation 3 3.9 Understand likely OUV responses – analyse the risks A useful way of analysing the risk to a site's OUV is to look at its key features and their attributes and assess the probability and significance posed by threats. For example: OUV feature Description of impact Reptile community of the site is among the most diverse in the world, with more than thirty-five species, 90 per cent of which are endemic Invasive predator damages populations Increased fire frequency changes vegetation, reducing habitat Reduced precipitation results in loss of wetland habitat Increased storm frequency and intensity results in eroded and sediment-laden habitats Phenology of spring grasses alters food for major prey during breeding season OUV feature Description of impact Probability Significance Reptile community Invasive predation on reptiles Fire frequency degrades habitat Precipitation frequency causes loss of wetlands Storm frequency and intensity damages habitats Phenology of spring grasses alters food for major prey during breeding season Improbable (low) Insignificant (low) Possible (medium) Significant (medium) Probable (high) Highly significant (high) Outstanding Universal Value Sensitivity, Vulnerability, Resilience Features and attributes Capacity to adapt Context – World Heritage, climate change Climate change Potential scenarios options Assessing risk Implementation logistics Prioritizing action Monitoring and evaluation Obviously the less resilient a site is, and therefore the more vulnerable it is to climate change, the higher the risk that it will suffer negative impacts from changes in climate. For the manager, the task is first to identify the sources of those risks, then to determine: – How likely are they to occur? | Impacts | 50 - 51 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Some events might be highly likely, but not significant to the OUV of a site. Others might be highly unlikely but disastrous if they do occur. A risk analysis is designed to help to identify outcomes that would be both relatively likely and relatively significant, and would therefore demand priority management attention.<br>54 3 Planning for adaptation In this example the site manager will focus efforts on improving capacity to manage fire in specific areas where damage to reptile habitat is most likely, while establishing a rigorous monitoring programme for the presence of invasive species. | Impacts | 51 - 52 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | An analysis of this sort allows the manager to identify key actions to sustain the OUV. Risk assessment is not a perfect science – it is informed guesswork based on the intuition, insights and expertise of the management team and colleagues, but it does provide a basis for focusing on issues that might otherwise be missed. This kind of assessment is therefore always most effective when carried out by a team that understands socio-economic as well as ecological dimensions. | Impacts | 52 - 52 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Worksheet 8: Features and attributes – climate change risk analysis Features Attributes Description of climate change impact(s) on the features and attributes Risk of impact – probability (high/medium/ low) Risk of impact – significance (high/medium/ low)<br>55 Planning for adaptation 3 3.10 Select and prioritize your actions While most action responses should be obvious, as in Example 10 above, it is worth making the following points: There may often need to be a number of action responses, not only to a range of risks that may be identified, but even to a single risk. | Impacts | 52 - 53 |

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| Organisation | Document | Quotation Content | Codes | Page |
|---|---|---|---|---|
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Outstanding Universal Value Sensitivity, Vulnerability, Resilience Features and attributes Capacity to adapt Context – World Heritage, climate change Climate change scenarios Potential options Assessing risk Implementation logistics Prioritizing action Monitoring and evaluation Example 11. Prioritizing management actions at Cloudey Island. | Impacts | 53 - 53 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | The Cloudey Island management team has assessed the risks to two of the features that contribute to their OUV, and then considered their possible responses against a set of criteria. They have also considered whether there are likely to be any conflicts between their responses and other features and attributes that contribute to the OUV. | Impacts | 53 - 53 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Key feature Impact Probability Significance (1) Natural scrub forest Increased storm events remove soils Increased salt spray increases soil salinity Encroachment by climate refugees seeking alternative land Wind-/sea-borne invasives impact on vegetation (2) Endemic landbirds Increased storm events impact on breeding cycles Predation by invasives Loss of vegetation through increased salinity/exposure Loss of water through increased salinity<br>56 3 Planning for adaptation Possible response actions Criteria PRIORITY ACTIONS Impact on other OUV features Technical expertise Logistics Human resources Time Finance No action Hn - - - - - - Monitor soil amount and condition - H M M H L C Buffer soils against prevailing winds ? H H H H H - Monitor soil salinity - H M M H L C Manage for colonization of less-exposed areas M M L H L - Work with partners to minimize risk of encroachment - H H H H H D Patrol and enforce regulations M M H H H H D Monitor for wind-/sea-borne invasives - H H H H M C Remove/control invasive predator Hp H H H H H A Create artificial nest sites in unexposed areas ? H H M M H D Monitor vegetation changes - H M M H H C Establish rain-fed watering points ? M M M L M B Monitor bird numbers, dispersal, nests, etc. Hp H H H H M A Note: in the first column, there are high impacts on OUV features that are both positive (Hp) and negative (Hn). | Impacts | 53 - 54 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | It is important to justify the scoring, providing as much information/evidence as possible to support it. In this example, the team has decided that ‘do nothing’ is not an option, as it will eventually result in loss of OUV. Some intervention will be necessary. | Impacts | 54 - 54 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Establishing rain-fed watering points for birds is also seen as a useful option, as there is little fresh water available in this karst ecosystem, and it is likely to be threatened by increased salinity. Providing the landbird population with a reliable source of water will help to sustain it. The conditions may not support managing for colonization of new areas by the plateau scrub, and it may in any case impact on other important habitats, and is therefore not seen as a priority. | Impacts | 54 - 54 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | The risk from climate refugees is not seen as an immediate threat, but it is a possibility, and work needs to be done to minimize this risk.<br>57 Planning for adaptation 3 Worksheet 9: Prioritizing action against criteria Possible response actions Criteria Priority actions 3.11 Implement your plan This section deals with some of the practicalities of implementing your responses. Much of this should be familiar in the context of management and action planning. | Impacts | 54 - 55 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Outstanding Universal Value Sensitivity, Vulnerability, Resilience Features and attributes Capacity to adapt Context – World Heritage, climate change Climate change Potential scenarios options Assessing risk Implementation logistics Prioritizing action Monitoring and evaluation<br>58 3 Planning for adaptation Example 12. Action plan and related tasks at Cloudey Island. | Impacts | 55 - 56 |

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| Organisation | Document | Quotation Content | Codes | Page |
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| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | 10 Training – monitoring/recording skills 11 Database as above 12 Monitoring equipment 13 Carry out monitoring/recording programme B Establish rain-fed watering points 1 Literature review/case studies 2 Identify and produce or purchase necessary materials 3 Monitoring equipment 4 Monitor/record C Monitor soil amount and condition Monitor soil salinity Monitor for wind-/sea-borne invasives Monitor vegetation changes 1 Training in necessary skills 2 Equipment as necessary 3 Database as above 4 Carry out periodic monitoring/recording programme D Create artificial nest sites in unexposed areas 1 Literature review/case studies 2 Identify appropriate locations 3 Carry out pilot programme 4 Evaluate 5 Carry out full programme based on assessment of need 6 Carry out monitoring/recording programme Patrol and enforce regulations 7 Training - knowledge of the law, interpersonal skills 8 Record/report incidents Work with partners to minimize risk of encroachment 9 Literature review/examples/incidence of events 10 Develop contacts list 11 Participate in round-table discussions 12 Raise awareness of issues 13 Maintain good relations The site management team recognizes the need to be as well informed as possible, so literature reviews, web searches, consultations with other managers, UNESCO, IUCN and other key organizations, and reviews of policy and law are all helpful. Strategic partnerships with universities or NGOs can often go a long way towards sharing some of this knowledge. | Impacts | 56 - 56 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Having listed the tasks linked to each option, the management team has now agreed on a logistical plan for implementing the tasks. It recognizes the need to start a training programme and to set up the system early on, and has timed its activities to coincide with appropriate seasonal factors such as breeding and rearing, different weather events, and optimal trapping times. It appreciates the need to minimize human presence on the island, and has timed monitoring activities to coincide with each other where possible, as this will also optimize logistics and minimize impact. | Impacts | 56 - 56 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | It also recognizes that some activities go beyond the twenty-four-month horizon of this initial programme.<br>59 Planning for adaptation 3 Months Actions 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 A 1 2 3 4 5 6 7 8 9 10 11 12 13 B 1 2 3 4 C 1 2 3 4 D 1 2 3 4 5 6 7 8 9 10 11 Round-table discussions as appropriate 12 13 Maintain good relations on an ongoing basis<br>60 3 Planning for adaptation 3.12 Monitoring and evaluation A wealth of research has demonstrated that well-designed monitoring of World Heritage habitats and species both on site and during off-site migration, as well as of key geology and hydrology indicators, will serve as an early warning, allowing managers to be proactive in reducing negative impacts where possible. | Impacts | 56 - 58 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Monitoring small isolated ecosystems such as pools, wetlands, wooded areas and scrubland will assist in assessing ecosystem-scale impacts. These small systems contribute disproportionately to regional landscape diversity, have easily assessed communities and physical structure, and serve as stepping stones in the landscape, facilitating plant and animal movements.30 At the community and ecosystem scale, climate monitoring has also demonstrated rapid recent changes across a landscape. For example, alpine streams in Switzerland have warmed, shown reduced nitrogen concentrations and reduced taxa richness and density of zooplankton in only a few decades.31 30 L. de Meester et al., 2005, Ponds and pools and model systems in conservation biology, ecology and end evolutionary biology Aquatic Conservation: Marine and Freshwater Ecosystems, Vol. 15, pp. 715–25. | Impacts | 58 - 58 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | 36 http://www.bto.org/science/international/out-africa 37 http://www.birdlife.org/africa Outstanding Universal Value Sensitivity, Vulnerability, Resilience Features and attributes Capacity to adapt Context – World Heritage, climate change Climate change scenarios Potential options Assessing risk Implementation logistics Prioritizing action Monitoring and evaluation<br>61 Planning for adaptation 3 Where appropriate, managers of African World Heritage sites might focus on such migrations as indicators of climate change, partly because of the contribution such observations would make to global research but also because these data are not well known, so careful data collection might be especially informative. Likewise, larger migratory animals provide essential information on changes in seasonal vegetation patterns. Scientists have successfully associated animal migrations and insect emergences with fine-scale climatic patterns.38 Amphibian communities in particular have shown the most dramatic climate change responses to date.39 In one study, autumn breeding amphibian populations are breeding later and winter breeding species are breeding earlier, with changes ranging from 5.9 to 37.2 days per decade.40 38 D. Senepathi et al., 2011, Climate change and the risks associated with delayed breeding in a tropical wild bird population, Proceedings of the Royal Society Part B – Biological Sciences, Vol. 278, pp. 3184–90. | Impacts | 58 - 59 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Butterflies have been shown to be very responsive to climatic changes over relatively short time frames (a few decades), and their responses are highly correlated with data on degree-days in the landscape.41 Those changes are important to World Heritage sites known for their biodiversity because IUCN's Red List may not adequately represent the risk that climate change poses to amphibian or dragonfly communities or to other small animals. | Impacts | 59 - 59 |

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| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | As described in Tool 11 of Enhancing our Heritage Toolkit, monitoring and assessment can help the site team to clarify its perception of climate change risks, its adaptive strategy, and the effectiveness of the adaptation actions it has decided to implement. As part of designing an effective assessment, the team will need to develop a range of indicators to measure the key outcomes from the adaptation plan; these should be directly related to the attributes of the site OUV. | Impacts | 59 - 59 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Figure 7: Climate change impacts on phenology. | Impacts | 59 - 59 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Source: National Academy of Sciences (2002), http://www.pnas.org/content/99/21/13379 3 Planning for adaptation 62 Monitoring is always limited by available resources, so the results and interpretations of a monitoring programme should be framed appropriately. For example, the experimental design (i.e. kinds and numbers of samples collected at various places and times) will dictate how well the site team understands the natural variance and the effects of an intervention such as an adaptation practice. Monitoring results might be phrased as statistically significant differences or as differences observed and recorded anecdotally. It will usually be valuable to consult a statistician, perhaps through a local university or ministry office, to assist with design and interpretation of monitoring results. | Impacts | 59 - 60 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | However, at regular timepoints during a programme, the management team should periodically pause and reflect on how effectively the site is being managed as well as how clearly the team understands the effects of its management. | Impacts | 62 - 62 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | The purpose of evaluation is to give feedback and information in order to adjust future activities, such as redirecting them elsewhere, reducing or intensifying them, allocating more or fewer resources, measuring new indicators or amending techniques. It is an opportunity to analyse previously unforeseen impacts, both positive and negative, that have occurred during the period and process in question. | Impacts | 62 - 62 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Does the site suffer from the adverse effects of development, neglect or any other degrading process? | Impacts | 63 - 63 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Do you have control over the processes causing deterioration? Have adaptation strategies been identified and implemented? | Impacts | 63 - 63 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | As well as evaluating the effects of any climate change adaptation strategy, it is important to recognize the need to evaluate the monitoring programme itself. Managers need to ensure that monitoring has been systematic, objectively verifiable, appropriately timescaled, adequately resourced, efficiently carried out and targeted at measurable and relevant indicators. | Impacts | 63 - 63 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | 3.13 Monitoring weather and climate patterns and their effects One of the most difficult steps is gathering evidence of climate trends and their effects. Given the increasing concerns about climate change and uncertainties, any monitoring should include a systematic record of prevailing local weather conditions and trends. In order to sustain any medium- to long-term record, site managers should begin to accumulate as much regional and local information as possible. | Impacts | 63 - 63 |

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| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Worksheet 11 summarizes a range of climatic factors and approaches to recording them. It is generic, not comprehensive, and requires adaptation to local circumstances, but may be a useful starting point in recording climate patterns and effects over the following decades. | Impacts | 63 - 63 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | The Bay of Bengal where the rivers Ganges, Brahmaputra and Meghna meet the sea, otherwise known as the Sundarbans. If the sea level was to rise by 45 cm worldwide as a consequence of climate change, 75 per cent of the Sundarbans mangroves could be destroyed and many species and millions of people would be affected. © NASA image created by Jesse Allen, Earth Observatory, using data obtained from the University of Maryland's Global Land Cover Facility<br>66 3 Planning for adaptation Worksheet 11: Monitoring weather/ climate patterns and effects Metrics/ comment Evidence /source Weather/climate factors Precipitation Days Amounts Sunny days Days of rain/ cloud-free weather Temperature Days of highest/lowest mean temperatures Blizzard/storm incidents (i.e. snow/rain with storm force winds) Dates Narrative Events Fire incidents Dates Narrative Flooding incidents Dates Narrative Drought Days in which demand for water exceeds supply Presence of sea ice Extent Volume Loss of river banks Lengths Amounts Rates Rockfall/mudslide incidents Dates Severity Narrative Silting Increases in silting volumes Avalanche incidents Dates Severity Narrative – known sites/new sites, etc. | Impacts | 63 - 64 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Melting Dates Rates Habitats Changes in vegetation patterns Dispersal – new species present Dominance Flowering/seeding patterns Dates Crop yields Increases/decreases of types Loss to weather patterns Loss to pest species Species Pests Increases/decreases in pest species New species present New patterns of predation/feeding Invasive species Increases/decreases in species New species present Insects Increases/decreases Hatching patterns – dates Birds Increases/decreases Hatching patterns – dates Nesting/feeding patterns – increases/decreases, new sites Migration dates Mammals Migration patterns – new sites, timescales Feeding patterns Birth rates Predation patterns Fish Non-native species Deaths caused resulting from algal blooms Migration and breeding patterns Availability of foods Conclusion<br>67 Conclusion 4 The Sundarbans (Bangladesh). | Impacts | 64 - 65 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | http://www.metoffice.gov.uk/precis/ Perry, J. A. 2011b. World Heritage hot spots: A global model identifies the 16 natural heritage properties on the World Heritage list most at risk from climate change. International Journal of Heritage Studies, Vol. 17, No. 5, pp. 426–41. | Impacts | 71 - 71 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | and Norris, K. 2011. Climate change and the risks associated with delayed breeding in a tropical wild bird population. Proceedings of the Royal Society Part B – Biological Sciences, Vol. 278, pp. 3184–90. | Impacts | 71 - 71 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | http://whc.unesco.org/en/activities/473/ UNESCO World Heritage Centre, 2007b, Climate Change and World Heritage – Report on predicting and managing the impacts of climate change on World Heritage and Strategy to assist States Parties to implement appropriate management responses. | Impacts | 71 - 71 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | http://whc.unesco.org/en/activities/474 UNESCO World Heritage Centre, 2008, Policy Document on the Impacts of Climate Change on World Heritage Properties. http://whc.unesco.org/en/CC-policy�document/ UNESCO World Heritage Centre. 2011. Preparing World Heritage Nominations. Resource Manual. | Impacts | 71 - 71 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | The Pilot Program for Climate Resilience (PPCR), approved in November 2008, was the first program under the SCF to become operational. Its objective is to pilot and demonstrate ways to integrate climate risk and resilience into core development planning, while complementing other ongoing activities. | Impacts | 73 - 73 |

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| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | It addresses one or more of the GEF Focal Areas, improving the global environment or advance the prospect of reducing risks to it. | Impacts | 74 - 74 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Application Deadline Varied Amount Varied URL Link http://www.thegef.org/gef/ The Adaptation Fund Eligibility Country Eligibility Developing country Parties to the Kyoto Protocol that are particularly vulnerable to the adverse effects of climate change including low-lying and other small island countries, countries with low-lying coastal, arid and semi-arid areas or areas liable to floods, drought and desertification, and developing countries with fragile mountainous ecosystems. | Impacts | 74 - 74 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | The Galápagos penguin has survived for thousands of years under the typical Galápagos conditions – indeed, these conditions have no doubt led to the evolution of the original arrivals into this endemic species. However, climate change in Galápagos is expected to be manifested through more frequent and more severe El Niño events. Given the huge effect of a severe El Niño on penguin populations, there is an increased risk that the penguin may disappear altogether. | Impacts | 80 - 80 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Water quantity and quality at Ichkeul is crucial to ensure a wetland ecosystem suitable for the migratory birds. The site lies at the bottom of a watershed and is separated from the sea via a small waterway leading to a salt lagoon. For this reason, the wetland's salinity is affected by the volume of water flowing into it. In the summer, salinity increases as water inflow decreases. In the winter, the reverse holds true – resulting in a delicate balance which provides suitable habitat quality for migratory birds. However, during prolonged Ichkeul National Park (Tunisia). © UNESCO/Marc Patry<br>84 6 Appendices droughts, and as sea levels rise, more sea water invades the wetland, increasing salinity to the point of having a detrimental impact on habitat quality. Compounding the challenges faced by the management agency, upstream capture and diversion of freshwater is increasingly an issue. The water is used to meet the needs of Tunisia's capital city, Tunis. | Impacts | 80 - 81 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | In this respect, a climate change mitigation project in the lands abutting the western boundary of this site may help to avoid a future scenario whereby local communities are compelled to turn to the World Heritage site for subsistence, thus undermining its Outstanding Universal Value. The Kariba REDD+ (United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries) project, certified under recognized international carbon verification standards, is selling carbon credits and funds are being applied to help communities improve agricultural practices, stabilize land use, and restore degraded forests. In so doing, the project will be improving the resilience of the World Heritage site, reducing the risk of incursions from surrounding communities in an age of climate change – when droughts are expected to be more common and severe. The project will also strengthen the connectivity of the site to the broader landscape, further supporting site resilience. | Impacts | 82 - 82 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | In Peru, Manú National Park (1,716,295 ha, inscribed 1987 with a minor modification in 2004) is a vast stretch of land that encompasses Andean highlands at over 4,000 m, to the Amazon basin. Not only does its large size and altitudinal gradients give its resident species room to adapt to climate variations, it is also surrounded by other protected lands, further buttressing it against climate change risks. | Impacts | 83 - 83 |

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| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | © Kim S. Gjerstad<br>87  Published within the  World Heritage Series  World Heritage manuals  Managing Tourism at World Heritage Sites:  a Practical Manual for World Heritage Site Managers  Gestión del turismo en sitios del Patrimonio Mundial:  Manual práctico para administradores de sitios del Patrimonio Mundial  (In English) November 2002; (In Spanish) May 2005  World Heritage papers2 Investing in World Heritage: Past Achievements, Future Ambitions  (In English) December 2002  World Heritage papers3 Periodic Report Africa  Rapport périodique pour l'Afrique  (In English and French) April 2003  World Heritage papers4 Proceedings of the World Heritage Marine Biodiversity Workshop,  Hanoi, Viet Nam. February 25–March 1, 2002  (In English) May 2003  World Heritage papers5 Identification and Documentation of Modern Heritage  (In English with two papers in French) June 2003  World Heritage papers6 World Heritage Cultural Landscapes 1992-2002  (In English) July 2004  World Heritage papers7 Cultural Landscapes: the Challenges of Conservation  Proceedings from the Ferrara workshop, November 2002  (In English with conclusions and recommendations in French) August 2004  World Heritage papers8 Mobilizing Young People for World Heritage  Proceedings from the Treviso workshop, November 2002  Mobiliser les jeunes pour le patrimoine mondial  Rapport de l'atelier de Trévise, novembre 2002  (In English and French) September 2003  World Heritage papers9 Partnerships for World Heritage Cities – Culture as a Vector for Sustainable   Urban Development. Proceedings from the Urbino workshop, November 2002  (In English and French) August 2004<br>Published within the World Heritage Series  88  World Heritage papers10 Monitoring World Heritage   roceedings from the Vicenza workshop, November 2002  (In English) September 2004  World Heritage papers11 Periodic Report and Regional Programme – Arab States 2000–2003  Rapports périodiques et programme régional – Etats Arabes 2000–2003  (In English) September 2004  World Heritage papers12 The State of World Heritage in the Asia-Pacific Region 2003  L'état du patrimoine mondial dans la région Asie-Pacifique 2003  (In English) October 2004; (In French) July 2005  World Heritage papers13 Linking Universal and Local Values:  Managing a Sustainable Future for World Heritage  L'union des valeurs universelles et locales :  La gestion d'un avenir durable pour le patrimoine mondial  (In English with the introduction, four papers and the conclusions and recommendations in French)  October 2004  World Heritage papers14 Archéologie de la Caraïbe et Convention du patrimoine mondial  Caribbean Archaeology and World Heritage Convention  Arqueología del Caribe y Convención del Patrimonio Mundial  (In French, English and Spanish) July 2005  World Heritage papers15 Caribbean Wooden Treasures  Proceedings of the Thematic Expert Meeting on  Wooden Urban Heritage in the Caribbean Region  4–7 February 2003, Georgetown – Guyana  (In English) October 2005  World Heritage papers16 World Heritage at the Vth IUCN World Parks Congress  Durban (South Africa), 8–17 September 2003  (In English) December 2005  World Heritage papers17 Promouvoir et préserver le patrimoine congolais  Lier diversité biologique et culturelle  Promoting and Preserving Congolese Heritage  Linking biological and cultural diversity  (In French and English) December 2005  World Heritage papers18 Periodic Report 2004 – Latin America and the Caribbean  Rapport périodique 2004 – Amérique Latine et les Caraïbes  Informe Periodico 2004 – América Latina y el Caribe  (In English, French and Spanish) March 2006  World Heritage papers19 Fortificaciones Americanas y la Convención del Patrimonio Mundial  American Fortifications | Impacts | 83 - 88 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Changement climatique et   patrimoine mondial  Rapport sur la prévision et la gestion des effets   du changement climatique sur le patrimoine mondial   et   Stratégie pour aider les États parties   à mettre en œuvre des réactions de gestion adaptées  22 rapports du patrimoine mondial  22Climate Change and World Heritage • Changement climatique et patrimoine mondial  Climate Change and World Heritage  Report on predicting and managing the impacts   of climate change on World Heritage   and  Strategy to assist States Parties to implement   appropriate management responses  World Heritage reports  World Heritage reports 22  PM_ClimateChange_cover 2/05/07 12:06 Page 1<br>Climate Change and World Heritage  Report on predicting and managing the impacts   of climate change on World Heritage   and  Strategy to assist States Parties to implement   appropriate management responses  PM_ClimateChange_22 UK 2/05/07 11:55 Page 1<br>Disclaimer  The authors are responsible for the choice and presentation of the facts contained in this publication and for the opinions  expressed therein, which are not necessarily those of UNESCO and do not commit the Organization. | Impacts | 1 - 3 |

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| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Reproduction is authorized, providing that appropriate mention is made of the source, and copies are sent to the UNESCO address below: World Heritage Centre UNESCO 7, place de Fontenoy 75352 Paris 07 SP France Tel : 33 (0)1 45 68 15 71 Fax : 33 (0)1 45 68 55 70 Website: http://whc.unesco.org Cover Photo: Snow and ice on Mount Kilimanjaro in 1993, and in 2002 © NASA/Goddard Space Flight Center Scientific Visualization Studio http://visibleearth.nasa.gov/ Editor: Augustin Colette, Climate Change Consultant, UNESCO World Heritage Centre Supervision and coordination: Kishore Rao, Deputy Director, UNESCO World Heritage Centre With contributions from: May Cassar (Centre for Sustainable Heritage, University College London, United Kingdom) Christopher Young (English Heritage, United Kingdom) Tony Weighell (Joint Nature Conservation Committee, United Kingdom) ICCROM ICOMOS David Sheppard (IUCN) Bastian Bomhard (IUCN) Pedro Rosabal (IUCN) UNESCO World Heritage Centre Publication based on Document WHC-06/30.COM/7.1 presented to the World Heritage Committee at its 30th session, Vilnius, Lithuania, 8-16 July 2006 Published in May 2007 by UNESCO World Heritage Centre This publication was made possible thanks to the financial contribution of the Government of Spain PM_ClimateChange_22 UK 2/05/07 11:55 Page 2<br>3 The 1972 UNESCO World Heritage Convention is the principal instrument for identifying and protect�ing, for the benefit of current and future generations, the outstanding natural and cultural heritage of the world, and encouraging international cooperation for its conservation. Climate change has now emerged as one of the most serious threats impacting on the conservation of this heritage. | Impacts | 3 - 4 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The World Heritage Committee has recognized this emerging threat and responded at its 29th session by launching an initiative to assess the impacts of climate change impacts on World Heritage and define appropriate management responses. Accordingly, a meeting of experts was held in March 2006 in order to prepare a Report and a Strategy to assist States Parties in addressing this threat, and these documents were endorsed by the Committee at its 30th session in July 2006. | Impacts | 4 - 4 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Protecting and managing World Heritage sites in a sustainable and effective manner is a shared responsibility under the Convention. Therefore, there is a need to publicize all available information on the threats posed by climate change and the potential measures for dealing with them. This pub�lication in the World Heritage Papers Series, comprising the report on 'Predicting and managing the effects of climate change on World Heritage' and a 'Strategy to assist States Parties to implement appropriate management responses' is part of that overall effort. | Impacts | 4 - 4 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Francesco Bandarin Director of the UNESCO World Heritage Centre Foreword PM_ClimateChange_22 UK 2/05/07 11:55 Page 3<br>PM_ClimateChange_22 UK 2/05/07 11:55 Page 4<br>5 Message from the UNFCCC Secretariat The UN Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol contain a number of provisions that are relevant for addressing the concerns of the World Heritage Convention including how to ensure adaptation to the adverse impacts of climate change on the World Heritage sites. | Impacts | 4 - 6 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | This Convention provides for countries to cooperate in preparing for adaptation to the impacts of climate change; develop and elaborate appropriate and integrated plans for coastal zone manage�ment, water resources and agriculture, and for the protection and rehabilitation of areas, particu�larly in Africa, affected by drought and desertification, as well as floods. | Impacts | 6 - 6 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The Framework Convention stipulates that developed countries should assist developing countries that are particularly vulnerable to the adverse effects of climate change in meeting costs of adap�tation to those adverse effects. It also addresses the specific needs of the Least Developed Countries (LDCs) for responding to climate change. | Impacts | 6 - 6 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Parties to the UNFCCC are: developing and submitting national reports containing inventories of greenhouse gas emissions by source and removals by sinks using agreed guidelines, adopting national programmes for mitigating climate change, developing strategies for adapting to its impacts, promoting technology transfer and the sustainable management of resources, enhancing greenhouse gas sinks and reservoirs (such as forests). In addition, the countries are taking climate change into account in their relevant social, economic, and environmental policies and cooperating in scientific, technical, and educational matters, as well as public awareness. | Impacts | 6 - 6 |

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| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Provisions and initiatives of the process of the United Nations Framework Convention on Climate Change relevant to the World Heritage Convention PM_ClimateChange_22 UK 2/05/07 11:55 Page 5<br>6 It is important to mention that national reports provide an opportunity for each Party to communi�cate its information, and where relevant, regional efforts to implement the Framework Convention based on agreed guidelines. The Conference of the Parties uses this information to assess and review the effective implementation of the Convention and assess the overall aggregated effect of steps taken by Parties. These reports have therefore the potential for and can serve to promote the national, regional and global effort aimed at mainstreaming climate change. They also provide for the consideration of climate change in development planning, poverty eradication and sustainable development. | Impacts | 6 - 7 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | In order to respond to the needs for assessing the impacts, vulnerability and adaptation, the UNFCCC secretariat has created a compendium on methods and tools to evaluate adaptation options and web pages to facilitate access to information on methods to evaluate adaptation options. It has conducted expert meetings and workshops with the participation of intergovernmental organizations, United Nations organizations and the community of users to identify opportunities for cooperation. | Impacts | 7 - 7 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | In 2006, the secretariat produced a technical paper on the application of environmentally sound tech�nologies for adaptation to climate change. This paper contains an overview of: the current knowl�edge and understanding of adaptation to climate change, a framework for assessing technologies for adaptation to climate change, the process of technology development and transfer as relevant to adaptation to climate change, examples of important technologies for adaptation in five sectors (coastal zones, water resources, agriculture, public health, and infrastructure), together with three case studies for each sector, and a synthesis of findings that have implications for climate policy. The paper argues that many technologies exist to adapt to natural weather-related hazards and that these technologies can also play an important part in reducing vulnerability to climate change. Hard and soft technologies are available to develop information and raise awareness, to plan and design adaptation strategies, to implement adaptation strategies, and to monitor and evaluate their per�formance. The paper provides examples of technologies that can be employed to accomplish them. | Impacts | 7 - 7 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | PM_ClimateChange_22 UK 2/05/07 11:55 Page 6<br>7 Realizing the need to obtain adequate funding for adaptation, COP 7 agreed to establish three new funds. The Special Climate Change Fund under the UNFCCC is to support, inter alia, the implemen�tation of adaptation activities where sufficient information is available, and the Least Developed Countries (LDCs) Fund should support, inter alia, the preparation and implementation of national adaptation programmes of action (NAPAs), which will communicate priority activities addressing the urgent and immediate needs and concerns of the LDCs, relating to adaptation to the adverse effects of climate change. A third fund, the Adaptation Fund, was established under the Kyoto Protocol. Only the Adaptation Fund is yet to become operational. | Impacts | 7 - 8 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The climate change process has also adopted the Nairobi Work Programme (NWP), the objective of which is to assist all Parties, in particular developing countries, including LDCs and SIDS, to improve their understanding and assessment of impacts, vulnerability and adaptation, and to make informed decisions on practical adaptation actions. It is also expected that the outcomes of this programme will include enhanced capacity at all levels to select and implement high priority adaptation actions; improved information and advice to the COP; enhanced cooperation among Parties, relevant organ�izations, business, civil society and decision makers; enhanced dissemination of information; and enhanced integration of adaptation with sustainable development. The focus areas of the NWP include: data and observations, methods and tools, climate modelling and downscaling, climate�related risks and extreme events, socio-economic information, adaptation planning and practices, technologies for adaptation research, and economic diversification. | Impacts | 8 - 8 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The World Heritage Committee could take advantage of the information and products that have been developed by other organizations through the climate change process. Many international organizations are undertaking considerable work on climate change impacts, vulnerability and adaptation, although not all of it is focused on decisions of the COP. | Impacts | 8 - 8 |

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| UNESCO | Climate Change and World Heritage - UNESCO 2007 | PM_ClimateChange_22 UK 2/05/07 11:55 Page 7<br>8 Ladies and Gentlemen, Climate change, through temperature increases (‘global warming’), sea-level rise, changes in pre�cipitation patterns, and increased frequencies of extreme weather events, is exerting considerable impacts on the Earth’s biodiversity. Recent findings by the scientific community suggest that global warming is causing considerable shifts in species spatial distributions, consistent with earlier pre�dictions by climate change models, and that spring is arriving earlier in temperate latitudes. Entire regions are also suffering from the effects of global warming; in particular, boreal and polar ecosys�tems. The incidence of pest outbreaks, particularly in forest ecosystems, is correlated with changes in ambient temperatures. The recent extinction of at least one vertebrate species, the golden toad, is directly attributable to the effects of contemporary climate change. | Impacts | 8 - 9 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Although past changes in the global climate resulted in major shifts in species ranges and marked reorganization of biological communities, landscapes, and biomes during the last thousands of years, these changes occurred in landscapes that were not as fragmented as today, and with little or no pressures from human activities. This means that on the one hand, current climate change cou�pled with other human pressures is stressing biodiversity far beyond the levels imposed by the global climatic change that occurred in the recent evolutionary past. On the other hand, this also suggests that while designing activities aimed at mitigating the impacts of climate change, biodi�versity considerations are essential. | Impacts | 9 - 9 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The impacts of climate change on biodiversity are of major concern to the Convention on Biological Diversity (CBD). At its fifth meeting in 2000, the Conference of the Parties drew attention to the seri�ous impacts of loss of biodiversity on terrestrial and marine ecosystems, and on people’s livelihoods and requested the Convention’s Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) to establish an ad hoc technical expert group which, between 2001 and 2003 carried out an in-depth assessment of the inter-linkages between biodiversity and climate change and its impli�cations for the implementation of the United Nations Framework Convention on Climate Change and its Kyoto Protocol. One of the report’s main findings is that there are significant opportunities for mitigating climate change, and for adapting to climate change while enhancing the conservation of biodiversity. The report also identifies a suite of tools, including the ecosystem approach of the Convention, that can help decision makers to assess the likely impacts and make informed choices when designing and implementing mitigation and adaptation projects. | Impacts | 9 - 9 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Statement by Ahmed Djoghlaf, Executive Secretary, Convention on Biological Diversity, delivered to the World Heritage and Climate Change Expert Meeting held at UNESCO, Paris, on 16 and 17 of March 2006 PM_ClimateChange_22 UK 2/05/07 11:55 Page 8<br>9 At its seventh meeting in 2004, the Conference of the Parties to the CBD further requested SBSTTA to develop advice for promoting synergy among activities to address climate change at the national, regional and international level, including activities to combat desertification and land degradation, and activities for the conservation of and sustainable use of biodiversity. Another expert group on biodiversity and adaptation to climate change was then established which undertook a detailed assessment on the integration of biodiversity considerations in the implementation of adaptation activities to climate change. SBSTTA welcomed the report at its eleventh meeting late last year, and requested the expert group to further refine its contents. One of the main findings of the report is that the ability of natural and managed ecosystems to adapt autonomously to climate change is insufficient to arrest the rate of biodiversity loss and that directed adaptation towards increasing ecosystem resilience be promoted. | Impacts | 9 - 10 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Collectively, the findings of these two reports provide comprehensive advice and guidance on how to mainstream biodiversity into climate change activities, at the biophysical level and at the level of tools and practical approaches. This information can be applied to the management of protected areas in general, and to World Heritage sites in particular, in order to mitigate and adapt to climate change. The Secretariat of the Convention on Biological Diversity is fully committed to exploring ways and means to enhance its collaboration with the World Heritage Committee on this topic, bearing in mind the challenge we all face to reduce significantly by 2010 the rate of biodiversity loss in the world as a contribution to poverty alleviation and to the benefit of all life on earth. | Impacts | 10 - 10 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | PM_ClimateChange_22 UK 2/05/07 11:55 Page 9<br>10 In the past few decades scientists have assembled a growing body of evidence showing the extent of change of the earth’s climate and that human activities play an important role in this change. This warning has led international, regional, and national organizations to develop dedicated programmes to assess and manage the impacts of climate change (e.g. the assessment recently conducted by the Convention on Biological Diversity). In this context, and following Decision 29 COM 7B.a of the World Heritage Committee in 2005, the present Report which has been prepared following the meeting of the Group of Experts in March 2006, aims at reviewing the potential impacts of climate change on World Heritage properties and suggesting appropriate measures to deal with them. | Impacts | 10 - 11 |

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| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The unprecedented rate of increase of global temperatures that has been recorded during the 20th century is the highest in the last millennium. And, according to the Intergovernmental Panel on climate Change (IPCC), most of this increase is attributable to human activities. The increase of global average atmospheric surface temperature is related to the greenhouse effect as a conse�quence of enhanced emissions of greenhouse gases. Increased global temperature is just one of the consequences of the impacts of human activities on the climatic equilibrium of the planet, with modifications of precipitation patterns, droughts, storminess, ocean temperature and acidification, sea-level rise, etc. Projections of numerical models show that this trend is very likely to be con�firmed in the future. Such changes are impacting on World Heritage properties, and if the trend is confirmed, these impacts will become even more threatening. | Impacts | 11 - 11 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | World Heritage cultural sites are also exposed to this threat. Ancient buildings were designed for a specific local climate. The migration of pests can have adverse impacts on the conservation of built heritage. Increasing sea level threatens many coastal sites. And the conditions for conservation of archaeological evidence may be degraded in the context of increasing soil temperature. But aside from these physical threats, climate change will impact on social and cultural aspects, with commu�nities changing the way they live, work, worship and socialize in buildings, sites and landscapes, possibly migrating and abandoning their built heritage. | Impacts | 11 - 11 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The fact that climate change poses a threat to the outstanding universal values (OUV) of some World Heritage sites has several implications for the World Heritage Convention. In this context, the relevance of the processes of the World Heritage Convention such as nominations, periodic report�ing, and reactive monitoring must be reviewed and suitably adjusted. It is also time to design Executive Summary PM_ClimateChange_22 UK 2/05/07 11:55 Page 10<br>11 appropriate measures for monitoring the impacts of climate change and adapting to the adverse consequences. In the worst case scenario, the OUV of a given site could be irreversibly affected (although it is recognized that climate change is one among a range of factors affecting the site), and the World Heritage Committee needs to consider the implications that this would have under the World Heritage Convention. | Impacts | 11 - 12 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Several actions can be contemplated in the short term to prevent the impacts of climate change on World Heritage properties, define appropriate adaptation measures, and enhance the sharing of knowledge among stakeholders. Such initiatives should be conducted in close collaboration with relevant bodies already involved in climate change and/or heritage and conservation issues, such as the United Nations Framework Convention on Climate Change (UNFCCC), the Intergovernmental Panel on Climate Change (IPCC), the Convention on Biological Diversity (CBD), the UNESCO Man and the Biosphere programme, the Ramsar Convention on Wetlands and the UNESCO conventions deal�ing with cultural heritage. | Impacts | 12 - 12 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The management plans of all sites potentially threatened by climate change should be updated to ensure sustainable conservation of their OUV in this context. The impacts of climate change on World Heritage properties must be assessed through appropriate monitoring and vulnerability assessment processes. Potential mitigation measures at the level of the sites and within the World Heritage network should also be investigated, although mitigation at the global and States Parties level is the mandate of the UNFCCC and its Kyoto Protocol. The importance of climate change threats also justifies the need to implement appropriately tailored risk-preparedness measures. As far as remedial measures are concerned, lessons learnt at several sites worldwide show the relevance of designing and implementing appropriate adaptations measures. The effectiveness of several actions has been demonstrated at a number of sites in the past, such as: increasing the resilience of a site by reducing non-climatic sources of stress, preventively draining a glacial lake to avoid the occur�rence of an outburst flood, improving dykes to prevent coastal flooding and supporting traditional methods to protect a site from sand encroachment. | Impacts | 12 - 12 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | PM_ClimateChange_22 UK 2/05/07 11:55 Page 11<br>PM_ClimateChange_22 UK 2/05/07 11:55 Page 12<br>Table of contents Page 3 Page 5 Page 8 Page 10 Page 15 Page 16 Page 16 Page 19 Page 20 Page 27 Page 28 Page 39 Page 40 Page 40 Page 41 Page 41 Page 42 Page 43 Page 45 Page 46 Page 50 Page 50 Foreword Francesco Bandarin Message from the UNFCCC Secretariat Statement by Ahmed Djoghlaf, Executive Secretary of the CBD Executive Summary Background Introduction Overview of climate change Predicting and managing the impacts of climate change on World Heritage Impacts of climate change on natural and cultural World Heritage Implications for the World Heritage Convention What can be done with respect to climate change and World Heritage? | Impacts | 12 - 14 |

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| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Strategy to assist States Parties to implement appropriate management responses Preamble: Objectives and requirements Preventive actions Corrective actions: Management, adaptation, and risk management Collaboration, cooperation, and sharing best practices and knowledge Legal issues Conclusion and steps ahead Appendices Expert Meeting of the World Heritage Convention on the Impacts of Climate Change on World Heritage Decision 29 COM 7B.a of the World Heritage Committee, 29th session (2005) Decision 30 COM 7.1 of the World Heritage Committee, 30th session (2006) 4 2 3 PM_ClimateChange_22 UK 2/05/07 11:55 Page 13<br>PM_ClimateChange_22 UK 2/05/07 11:55 Page 14<br>Background 15 Doñana National Park, Spain © Renato Valterza PM_ClimateChange_22 UK 2/05/07 11:55 Page 15<br>Introduction The scientific community now widely agrees on the fact that human activities are disturbing the fragile climatic equilibrium of our planet. The resulting climate change is defined by the United Nations Framework Convention on Climate Change (UNFCCC), in its Article 1, as 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural cli�mate variability observed over comparable time periods'. The UNFCCC thus makes a distinction between 'climate change' attributable to human activities altering the atmospheric composition, and 'climate variability' attributable to natural causes. | Impacts | 14 - 17 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Predicting and managing the impacts that climate change will have on World Heritage is a real chal�lenge, but considering the importance of the issue, it is now timely to face this problem. | Impacts | 17 - 17 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Lastly, the IPCC also insists on the fact that 'the impact of climate change is projected to have differ�ent effects within and between countries. The chal�lenge of addressing climate change raises an important issue of equity'. | Impacts | 17 - 17 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | But the temperature increase is just one of the many indi�cators for the ongoing climate change that is observed and expected to increasingly impact on people and their environments, including species, ecosystems and pro�tected areas around the world. Changes in climate pat�terns are already being felt now at the local scale, as shown by observations, for instance, in the United Kingdom: temperatures are already rising, provoking more rainfall in the wetter north of the country but less rainfall in the dryer south. Indirect consequences include the cost of weather related natural catastrophes that sig�nificantly increased since 1953, according to the records of insurance companies worldwide. | Impacts | 17 - 17 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Projected climate change The extent of future temperature increase is difficult to project with certainty since scientific knowledge of the processes is incomplete and the socio-economic factors that will influence the magnitude of such increases in the future are also uncertain. And even if carbon dioxide emis�sions are reduced significantly over the coming years, sig�nificant increases in temperature and sea-level rise would occur, resulting in major changes in climatic patterns men�tioned above (rainfall regimes, risks of drought, intensity of rainfall, flooding, storms, tropical cyclones, etc). These effects would be even more exacerbated in a 'business as usual' scenario. | Impacts | 18 - 18 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | 17 Background The economic losses from catastrophic weather events have risen globally 10-fold (inflation-adjusted) from the 1950s to the 1990s, much faster than can be accounted for with simple inflation. The insured portion of these losses rose from a neg�ligible level to about 23% in the 1990s. The total losses from small, non-catastrophic weather-related events (not included here) are similar. Part of this observed upward trend in weather-related disaster losses over the past 50 years is linked to socio-economic factors (e.g., population growth, increased wealth, urbanization in vulnerable areas), and part is linked to regional climatic factors (e.g., changes in precipi�tation, flooding events). | Impacts | 18 - 18 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | © IPCC, 2001* PM_ClimateChange_22 UK 2/05/07 11:55 Page 17<br>PM_ClimateChange_22 UK 2/05/07 11:55 Page 18<br>19 Predicting and managing the impacts of climate change on World Heritage The Great Barrier Reef, Australia © GBRMPA Image collection 2<br>PM_ClimateChange_22 UK 2/05/07 11:55 Page 19<br>20 2 Predicting and managing the impacts of climate change on World Heritage Impacts of climate change on natural and cultural World Heritage Impacts of climate change on natural World Heritage Brief overview of the main impacts Most of the changes in the climatological indicators listed above may have adverse impacts on natural World Heritage properties: • Ice caps, glaciers and permafrost, sea ice, ice and snow cover especially in polar and mountain regions are melting. | Impacts | 18 - 21 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | • Temperatures and atmospheric CO2 concentrations are increasing and impact directly or indirectly on plant and animal species and, in turn, on ecosystems. | Impacts | 21 - 21 |

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| UNESCO | Climate Change and World Heritage - UNESCO 2007 | • The growing season of plants is lengthening, plant and animal ranges are shifting poleward and upward in ele�vation, and with the help of increased temperatures and atmospheric CO2 concentrations, invasive alien species increasingly impact upon indigenous species (see follow�ing section on terrestrial ecosystems). | Impacts | 21 - 21 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | All these physical and biological changes affect ecosystem functioning, such as in relation to nutrient cycling, and the provision of ecosystem goods and services with significant impacts on human livelihoods. Thus, socio-economic activ�ities, including agriculture, fishery and tourism, are also being impacted on increasingly, for example through changes in freshwater supply. Finally, climate change inter�acts with other global change drivers such as land-use change and socio-economic change, potentially exacer�bating impacts on people and their environment. | Impacts | 21 - 21 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Impacts on terrestrial biodiversity Climate change will impact a wide range of biomes. As far as terrestrial biodiversity is concerned, the range of poten�tial impacts includes: For species distributions: • Individualistic species responses in latitudinal and altitu�dinal directions. | Impacts | 21 - 21 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | • Species range shifts/losses due to range expansions, con�tractions and eliminations. | Impacts | 21 - 21 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | • Species range shifts relative to reserve boundaries: net loss/gain of species in reserves. | Impacts | 21 - 21 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Consequently, various types of terrestrial ecosystems are at risk, including: - Small and/or isolated protected areas. | Impacts | 21 - 21 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Illustrative examples of impacts of climate change on ter�restrial biodiversity are given in Box 1 and Box 2 on p.19 for the World Heritage sites of Doñana National Park (Spain) and Cape Floral Region (South Africa). | Impacts | 21 - 21 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | BOX 1 Potential climate change impacts on the Doñana National Park (Spain) 1 The Doñana National Park and World Heritage property, in southern Spain, is the largest and most comprehensive conservation area in Iberia and covers an area of 50,000 hectares. | Impacts | 21 - 21 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | PM_ClimateChange_22 UK 2/05/07 11:55 Page 20<br>21 Predicting and managing the impacts of climate change on World Heritage 2 Dessication of the wetland areas of the Park as a result of increased water use has resulted in the loss of some 100 plant species during the last 80 years. | Impacts | 21 - 22 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The winter droughts of the 1990s have already had a severe impact upon the area, a situation that is likely to become considerably more acute in the future as the climate of southern Spain dries. The park exists at an altitude between sea level and 40 m. Sea level in the region has risen by about 20 cm over the last century and future rises in sea level may further threaten these remaining wetland areas through saltwater inundation which threatens the survival of this impor�tant migratory bird habitat. Scenarios suggest further rises in sea level of between 20 cm and 110 cm by the end of next century. | Impacts | 22 - 22 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | BOX 2 Potential climate change impacts on the Cape Floral Region (South Africa) 2 The Cape Floral Region World Heritage site consists of 8 protected areas covering 553 000 ha and characterised by an outstanding plant diversity, density and endemism. Based on supporting evidence by experiments, observations and modelling, climate change might be the most significant threat facing this diversity over the next 50 to 100 years. Projected changes in soil moisture and winter rainfall could result in a changed species distribution. This would affect the range restricted and locally rare species with limited dispersal ability and the climate sensitive relict wetland species that characterize the floristic region. Climate change might also affect the values of the site through drought mortality, the breaking up of highly specialized mutualisms and impacts on existing disturbance regimes such as fire. The first impacts of climate change on the region’s biodiversity are already becoming apparent and many more impacts are expected. Bioclimatic modelling provides an excellent risk assessment but key knowledge gaps need to be closed by experimental and observational studies. | Impacts | 22 - 22 |

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| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Potential strategies include investing in focussed research and developing a monitoring system, perhaps with the involvement of the public. Conservation planning should also be integrated with climate risk assessment and a coordinated regional effort should be established to analyse information and assess the risk of biodiversity loss. It is also important to increase the topographic diversity and landscape connectivity of protected areas by creating migratory corridors, to reduce or remove other stresses on the ecosystem and to strengthen risk preparedness, in particular for fires. | Impacts | 22 - 22 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Impacts on mountainous ecosystems Increasing atmospheric temperature is causing glaciers to melt worldwide. As far as mountainous glaciers are con�cerned, widespread retreats are being observed and will cause the melting of a number of glaciers, among which many are listed as World Heritage sites. The melting of gla�ciers has obvious consequences for the aesthetic values of these sites. But it will also have an impact on surrounding ecosystems: • Glacier melting leads to the formation of glacial lakes. | Impacts | 22 - 22 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Illustrative examples of impacts of climate change on mountainous glaciers are given in Box 3 and Box 4 on p.20 for the Sagarmatha National Park (Nepal) and the Huascarán National Park (Peru) World Heritage sites. | Impacts | 22 - 22 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | PM_ClimateChange_22 UK 2/05/07 11:55 Page 21<br>BOX 3 Potential climate change impacts on the Sagarmatha National Park (Nepal) 3 In Sagarmatha, Nepal, air temperatures had been ris�ing by 1 °C since the seventies, leading to a decrease in snow and ice cover of 30% in the same period and replacing a 4000 m high glacier on Mount Everest by a lake. Glacier lake outburst floods are now much more frequent, creating serious risks for human popu�lations and having implications for the water supply in South Asia and the flow of major rivers such as the Ganges, Indus and Brahmaputra. | Impacts | 22 - 23 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | BOX 4 Potential climate change impacts on the Huascarán National Park (Peru) 4 A number of effects of climate change are being monitored and studied at the Huascarán National Park, in particular the accelerated glacier melting, resulting in changes in the quality and quantity of water coming from the mountains and in greater risks of land slides and lake outburst events and the migration of certain species to higher altitudes. Such outburst floods in the Huascarán National Park threaten a nearby cultural World Heritage site: Chavin. Other effects such as the disappearance of certain native species, the increased pressure on certain park resources and the alteration of rain patterns are not yet quantified. Two million people are depending on water originating from the National Park and their demand on water resources is increasing. | Impacts | 23 - 23 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Impacts on marine ecosystems The rise of ocean temperature threatens many marine species among which coral reefs that, in many areas, live close to their upper thermal limit. Several coral reefs are listed as World Heritage sites, partly because they host infi�nitely complex ecosystems in which a myriad of species of fish and aquatic vegetation are interlocked in a mutually profitable interdependence (see the example in Box 5). | Impacts | 23 - 23 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | BOX 5 Potential climate change impacts on the Great Barrier Reef (Australia) 5 The Great Barrier Reef (GBR) is the world's largest coral reef ecosystem in the world (2100 km, 344,400 km2; and 2900 individual reefs). It is also among the world's most diverse ecosystems (1500 species of fish, 400 species of corals, and several thousands species of molluscs) and was listed under all 4 natural World Heritage criteria. The GBR Marine Park Authority (GBRMPA) is the responsible Australian Government authority, and the site is divided into zones which permit a range of activities under controls. | Impacts | 23 - 23 |

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| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The sustainability of this World Heritage site is sensitive to any change in the following climate parameters: sea level rise, sea temperature increase, storm frequency and intensity, precipitation, drought, land run-off, changing oceanic circulation, and ocean acidity. Of central concern are the acute and cumula�tive impacts of coral bleaching, which are triggered when the GBR experiences anomalously high water temperatures. It is important to note, however, that coral bleaching is a major threat to coral reefs every�where. And the threat is not amenable to manage�ment in the short to medium term.6 In 1998 and 2002, major bleaching events occurred in the region. In 2002, between 60 and 95 per cent of corals were affected. Corals of most of the reefs recovered well but a small percentage (less than 5 per cent) of reefs suffered high mortality, losing between 50 and 90 per cent of their corals. As a response, a climate change Response Programme (2004 – 08) was developed to better understand and respond to climate change threats and to prepare an annual Coral Bleaching Response Plan and a climate change Action Plan. The Coral Bleaching Response Plan aims at detecting and measuring bleaching and other short and long term impacts (Satellite imagery, aerial and underwater surveys, community observations) and has received worldwide recognition (and was adapted for the Florida Keys and Indonesia for example). The climate change Action Plan aims at sustaining ecosystems, industries, and communities by identify�ing and implementing relevant management actions, adapting policy and fostering collaborations. | Impacts | 23 - 23 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | 22 2 Predicting and managing the impacts of climate change on World Heritage 3. Communication of Martin Parry (Co-chair of working group II of the Intergovernmental Panel on Climate Change) at the expert meeting on Climate Change and World Heritage (UNESCO HQ, Paris, 16-17 March, 2006) 4. Communication of Pablo Dourojeani (the Mountain Institute) at the expert meeting on Climate Change and World Heritage (UNESCO HQ, Paris, 16-17 March, 2006) 5. Communication of Greg Terrill (Assistant Secretary, Heritage Division Australian Department of Environment and Heritage) at the expert meeting on Climate Change and World Heritage (UNESCO HQ, Paris, 16-17 March, 2006) 6. Australian Institute of Marine Science Annual Report 2001-2, p 18 PM_ClimateChange_22 UK 2/05/07 11:55 Page 22<br>The GBR management actions are recognized as world's best practice7 and that the GBR has relatively low bleaching to date, but further events will be inevitable. The main challenge is to increase broad resilience, which requires multifactor efforts and in many respects adaptation, continuation and enhancement of current efforts. To increase the broad resilience of the GBR Marine Park, in 2004, the GBRMPA increased the percentage of no-take area within the Marine Park from 5% to 33%. Also, the Australian Government is working closely with the Queensland Government on the Reef Water Quality Protection Plan, which aims to halt and reverse the decline in water quality entering the Marine Park by 2013. | Impacts | 23 - 24 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Impacts of climate change on cultural World Heritage Climate change has implications for natural and societal systems (agriculture, human health, forestry, and infra�structure) including natural and cultural heritage. The assessment of the impacts of climate change on cultural World Heritage must thus account for the complex inter�actions within and between natural, cultural and societal aspects. | Impacts | 24 - 24 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Direct physical impacts of climate change on cultural World Heritage A number of direct impacts of climate change can be expected to play a role: • Archaeological evidence is preserved in the ground because it has reached a balance with the hydrological, chemical and biological processes of the soil. Short and long cycles of change to these parameters may result in a poorer level of survival of some sensitive classes of material (see the example for the cultural sites in the Yukon Territory, Canada, see Box 6) • Historic buildings have a greater intimacy with the ground than modern ones. They are more porous and draw water from the ground into their structure and lose it to the environment by surface evaporation. Their wall surfaces and floors are the point of exchange for these reactions. Increases in soil moisture might result in greater salt mobilisation and consequent damaging crys�tallisation on decorated surfaces through drying. | Impacts | 24 - 24 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | • Flooding may damage building materials not designed to withstand prolonged immersion, and post flooding drying may encourage the growth of damaging micro-organisms such as moulds (see the example for the World Heritage sites of the Historic City of London, Box 7 below). Rapid flowing water may also erode buildings. | Impacts | 24 - 24 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | • Increases in storminess and wind gusts can lead to struc�tural damage. | Impacts | 24 - 24 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | • Movable heritage may be at risk from higher levels of humidity, higher temperatures and increased UV levels. | Impacts | 24 - 24 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | • Desertification, salt weathering and erosion is threaten�ing cultural heritage in desert areas such as the Chinguetti Mosque in Mauritania (see Box 8 on p. 22). | Impacts | 24 - 24 |

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| UNESCO | Climate Change and World Heritage - UNESCO 2007 | BOX 6 Potential impacts of climate change on cultural sites in the Yukon Territory (Canada)8 The 19th-century whalers' settlements of Herschel Island in the Yukon Territory (Canada) are currently on the Canadian World Heritage Tentative List for their outstanding cultural value (Site of Ivvavik / Vuntut / Herschel). However, the deterioration of the per�mafrost is leading to ground slumping which is affecting many of the historic grave markers and even caskets buried in graveyards around Pauline Cove. | Impacts | 24 - 24 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | BOX 7 Potential impacts of climate change on World Heritage sites of London, UK (Westminster Palace, Westminster Abbey and Saint Margaret's Church; Tower of London; Maritime Greenwich) The United Kingdom Climate Impacts Programme has suggested that the sea level will rise in the Thames estu�ary between 0.26 m and 0.86 m higher on average by the 2080s than it was between 1961 and 1990. The Thames estuary is tidal with tides being occasionally enhanced by weather conditions in the North Sea. | Impacts | 24 - 24 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | 23 Predicting and managing the impacts of climate change on World Heritage 2 7. Global Coral Reef Monitoring Network 'Status of coral reefs of the world 2004'; WWF 'Climate change and World Heritage sites', Australia, 2006; D. Rothwell, 'Global Climate Change and the GBR', report for EDO, CANA, Greenpeace, Australia, 2004 8. Communication of Douglas Olynyk (Yukon Territorial Government and ICOMOS Canada) at the expert meeting on Climate Change and World Heritage (UNESCO HQ, Paris, 16-17 March, 2006) PM_ClimateChange_22 UK 2/05/07 11:55 Page 23<br>One overtopping of the Barrier will have an indirect cost to UK economy of £30 billion and it can be predicted that flooding will inundate at least the World Heritage site closest to the Thames, namely the Palace of Westminster and the Tower of London. | Impacts | 24 - 25 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | BOX 8 Potential impacts of climate change on the Chinguetti mosque (Mauritania) This World Heritage site is situated on the edge of the Sahara desert. It is home to a remarkable collection of Islamic manuscripts as well as a 13th-century mosque with a massive square minaret towering over the town. | Impacts | 25 - 25 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The combination of the decline in trade and loss in income has increased the threat from the encroaching desert which constantly threatens the town's build�ings, especially the mosque. Chinguetti's buildings are also regularly subjected with seasonal flooding with the subsequent erosion caused by the water run-off. | Impacts | 25 - 25 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Social impacts of climate change on cultural World Heritage 9 Changes to cultural heritage caused by climate change cannot be viewed separately from changes in society, demographics, people's behaviour, the impact of conflict�ing societal values and land-use planning which will also need to evolve in the face of climate change. In World Heritage terms, cultural heritage is now defined very widely to include individual sites, buildings or structures as well as urban or rural landscapes which may include dynamics that are not only subject to climate change but also contribute to climate change. | Impacts | 25 - 25 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Cultural impacts of climate change on cultural World Heritage10 Climate change will have physical, social and cultural impacts on cultural heritage. It will change the way people relate to their environment. This relationship is charac�terised by the way people live, work, worship and socialize in buildings, sites and landscapes with heritage values. | Impacts | 25 - 25 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Climate change and the socio-economic changes that will result will have a greater possible impact on the conserva�tion of cultural heritage than climate change alone. This combined effect needs to be explored more fully and this can be done in the context of World Heritage, as World Heritage sites provide excellent examples of test cases. | Impacts | 25 - 25 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Interconnection of physical and social impacts Many World Heritage sites are living places which depend on their communities to be sustained and maintained. | Impacts | 25 - 25 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Climate change has consequences for the whole of human existence and the products of human creativity. In the case of cultural World Heritage sites these consequences will be manifest in at least two principal ways: direct physical effects on the site, building or structure and the effects on social structures and habitats that could lead to changes in, or even the migration of, societies that are currently sustaining World Heritage sites. The implications of the latter are not well understood, even if the nature of the impacts will vary depending on the nature of the World Heritage sites. | Impacts | 25 - 25 |

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| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Interconnection of physical and cultural impacts  The character of cultural heritage is closely related to the  climate. The rural landscape has developed in response to  the plant species that are able to flourish in different cli�matic regimes. The urban landscape and the built heritage  have been designed with the local climate in mind. The  stability of cultural heritage is, therefore, closely tied to its  interactions with the ground and the atmosphere. Where  World Heritage sites are in use by local communities there  may be pressure for significant adaptive changes to allow  use and occupation to continue. Even where this is not the  case, there can be very direct physical effects. | Impacts | 25 - 25 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Summary of changes in climate change indicators  and related impacts on cultural heritage  In the context of complex interactions such as mentioned  in the previous paragraph, one needs to define indicators  to assess the overall impact of climate on cultural World  Heritage. Climate change can be subtle and can occur over  a long period of time. However, some climate change  parameters such a freezing, temperature and relative  humidity shock can change by large amounts over a short  period of time. To identify the greatest global climate  change risks and impacts on cultural heritage, the scien�tific community uses the climate parameters tabulated on  the opposite page (Table 1). | Impacts | 25 - 25 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | 24  2 Predicting and managing the impacts of climate change on World Heritage  9. The issues mentioned in this paragraph refer to cultural heritage  properties, although, to some extent, it also applies to natural   heritage properties. 10. Idem  PM_ClimateChange_22 UK 2/05/07 11:55 Page 24  25  Predicting and managing the impacts of climate change on World Heritage 2  Climate indicator   Atmospheric moisture  change  Temperature change  Sea-level rises  Wind  Desertification  Climate and pollution  acting together  Climate and biological  effects  Physical, social and cultural impacts on cultural heritage  - pH changes to buried archaeological evidence  - Loss of stratigraphic integrity due to cracking and heaving from changes in sediment moisture  - Data loss preserved in waterlogged / anaerobic / anoxic conditions  - Eutrophication accelerating microbial decomposition of organics  - Physical changes to porous building materials and finishes due to  rising damp  - Damage due to faulty or inadequate water disposal systems; historic  rainwater goods not capable of handling heavy rain and often difficult  to access, maintain, and adjust  - Crystallisation and dissolution of salts caused by wetting and drying  affecting standing structures, archaeology, wall paintings, frescos and  other decorated surfaces  - Erosion of inorganic and organic materials due to flood waters  - Biological attack of organic materials by insects, moulds, fungi, inva�sive species such as termites  - Subsoil instability, ground heave and subsidence  - Relative humidity cycles/shock causing splitting, cracking, flaking and  dusting of materials and surfaces  - Corrosion of metals  - Other combined effects eg. increase in moisture combined with fertilisers and pesticides  - Deterioration of facades due to thermal stress  - Freeze-thaw/frost damage  - Damage inside brick, stone, ceramics that has got wet and frozen  within material before drying  - Biochemical deterioration  - Changes in 'fitness for purpose' of some structures. For example  overheating of the interior of buildings can lead to inappropriate   alterations to the historic fabric due to the introduction of engineered  solutions  - Inappropriate adaptation to allow structures to remain in use  - Coastal erosion/loss  - Intermittent introduction of large masses of 'strange' water to the site,  which may disturb the metastable equilibrium between artefacts and soil  - Permanent submersion of low lying areas  - Population migration  - Disruption of communities  - Loss of rituals and breakdown of social interactions  - Penetrative moisture into porous cultural heritage materials  - Static and dynamic loading of historic or archaeological structures  - Structural damage and collapse  - Deterioration of surfaces due to erosion  - Erosion  - Salt weathering  - Impact on health of population  - Abandonment and collapse  - Loss of cultural memory  - Stone recession by dissolution of carbonates  - Blackening of materials  - Corrosion of metals  - Influence of bio-colonialisation  - Collapse of structural timber and timber finishes  - Reduction in availability of native species for repair and maintenance   of buildings  - Changes in the natural heritage values of cultural heritage sites - Changes in appearance of landscapes  - Transformation of communities   - Changes the livelihood of traditional settlements  - Changes in family structures as sources of livelihoods become more  dispersed and distant  Climate change risk  - Flooding (sea, river)  - Intense rainfall  - Changes in water-table  levels   - Changes in soil chemistry  - Ground water changes  - Changes in humidity cycles  - Increase in time of wetness  - Sea-salt chlorides  - Diurnal, seasonal, extreme  events (heat waves, snow  loading)  - Changes in freeze-thaw and  ice storms, and increase in  wet frost  - Coastal flooding  - Sea-water incursion  - Wind-driven rain  - Wind-transported salt  - Wind-driven sand  - Winds, gusts and changes  in direction  - Drought  - Heat waves  - Fall in water table  - pH precipitation  - Changes in deposition of  pollutants  - Proliferation of invasive   species  - Spread of | Impacts | 25 - 27 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Of the 110 responses received from 83 States Parties, 72%  acknowledged that climate change had an impact on their  natural and cultural heritage. Forty-six countries men�tioned that they were undertaking specific actions to deal  with the issue although most of these actions were limited  to the monitoring of the impacts of climate change. Thirty�nine countries reported dedicated research was underway. | Impacts | 27 - 27 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Seventy-one countries declared themselves to be inter�ested in participating in programs and initiatives aimed to  address climate change impact on World Heritage sites. | Impacts | 27 - 27 |

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| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The climate change impacts observed for natural World Heritage properties were: • Glacial retreat and glacier melting (19 sites). | Impacts | 27 - 27 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | • Loss of biodiversity (17 sites). | Impacts | 27 - 27 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | • Coastal erosion (4 sites). | Impacts | 27 - 27 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | • Erosion (both wind and water driven) (8 sites). | Impacts | 27 - 27 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | 26 2 Predicting and managing the impacts of climate change on World Heritage Natural Both natural / cultural Cultural 71% 46% 8% Type of sites affected by climate change Coastal and marine sites Glaciers and mountains Terrestrial biodiversity reserves Others 21% 14% 16% 28% Type of biomes for natural World Heritage sites Glacial retreat and melting Sea level rise Loss of biodiversity Species migration Rainfall pattern change and drought Wildffre frequency Coral bleaching Coastal erosion Other 20% 17% 19% 11% 9% 6% 12% Threats of climate change reported for natural World Heritage properties 4% 3% Hurricane and storm frequency Sea level rise Erosion Floods Rainfall pattern change Outdoor painting damage Droughts Other 9% 8% 11% 4% 4% 3% 7% Threats of climate change reported for cultural World Heritage properties 4% PM_ClimateChange_22 UK 2/05/07 11:55 Page 26<br>Implications for the World Heritage Convention11 Introduction The World Heritage Convention is a unique multilateral environmental agreement as it recognizes that parts of the cultural and natural heritage are of outstanding universal value and therefore need to be preserved as part of the heritage of humankind. The key test for inclusion of cul�tural and natural properties on the World Heritage List is that of meeting the criteria of outstanding universal value (OUV), which are assessed through a rigorous evaluation process by the Advisory Bodies of the World Heritage Convention. Once the properties are inscribed on the World Heritage List they benefit from the World Heritage Convention as an important tool for international cooper�ation; however their conservation and management is the primary responsibility of the State Party where the property is located (Article 4). | Impacts | 27 - 28 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | In a sense natural World Heritage properties represent a unique subset of the world's global network of over 100,000 protected areas. Since natural World Heritage sites are distributed around the world and represent a variety of ecosystems they are exposed to impacts from climate change of different kinds, magnitudes and rates. | Impacts | 28 - 28 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Ongoing climate change threats on World Heritage The present and potential future impacts of climate change on biodiversity and ecosystems are well studied and documented. Many of the impacts of climate change mentioned in section 2.1.1 are already being observed, or are expected to occur in the short to medium term, in a number of natural World Heritage sites12. Climate change could amplify and accelerate major existing management problems and threats affecting the integrity of these prop�erties: species and habitat change, resource extraction, inefficient site management, invasive species and, in some cases, armed conflicts. In addition a number of natural World Heritage properties show already high natural sensitivity and low capacity to cope with these social and environmental impacts; which increasingly require the use of innovative adaptive management mechanisms. | Impacts | 28 - 28 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Therefore, within the context of the World Heritage Convention's legal framework, climate change poses a number of critical questions: • Should a site be inscribed on the World Heritage List while knowing that its potential OUV may disappear due to climate change impacts? | Impacts | 28 - 28 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | • Should a site be inscribed on the List of World Heritage in Danger or deleted from the World Heritage List due to the influence of impacts that are beyond the control of the concerned State Party? | Impacts | 28 - 28 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | • Given the long-term nature of climate change impacts should the consideration of OUV be deliberately consid�ered in a longer time frame context? | Impacts | 28 - 28 |

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| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The questions posed above are pertinent as there is little doubt that climate change will impact on the natural val�ues and integrity of World Heritage sites, thus affecting their outstanding universal value and, potentially, their listing as a natural World Heritage property. If a site was inscribed for its glaciers, and the glaciers melt, is it 'no glaciers – no World Heritage site'? A similar problem may arise from climate change-related degradation of coastal ecosystems due to sea-level rise. Natural disasters trig�gered by extreme weather events may cause severe and irreversible impact on geological, geomorphologic and physiogeographic heritage (criterion viii). Most impor�tantly, physical and biological changes affect ongoing ecological and biological processes and natural habitats through species range shifts and extinctions, changes in community composition and configuration and changes in ecosystem functioning (criteria ix and x). Potentially, the World Heritage List as we know it today could be changed drastically. | Impacts | 28 - 28 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | 27 Predicting and managing the impacts of climate change on World Heritage 2 11. Most issues mentioned in this section (prepared by IUCN) refer to natural heritage properties, while the majority of them apply also to cultural heritage. | Impacts | 28 - 28 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | 12. Dudley, 2003. No Place to Hide: Effects of Climate Change on Protected Areas. WWF Climate Change Programme, Berlin. Online: www.worldwildlife.org/climate/pubs.cfm. | Impacts | 28 - 28 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | PM_ClimateChange_22 UK 2/05/07 11:55 Page 27<br>Implementing appropriate management strategies At the same time, extreme weather events, physical and bio�logical changes and increasing pressures from other human activities affect the conditions of integrity of the properties, thus requiring appropriate adaptation and mitigation man�agement. Therefore, should this new management require�ment be considered a prerequisite for a site to meet the conditions of integrity? The integrity required for inscription of natural World Heritage sites might however prove to be an asset when it comes to alleviating climate change impacts through 'healthy' landscapes and seascapes. | Impacts | 28 - 29 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Climate change impacts are also likely to give added impor�tance to well managed and designed buffer zones which link World Heritage sites with the surrounding landscape. | Impacts | 29 - 29 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The possible implications for the Operational Guidelines As mentioned above, accounting for climate change impacts in the evaluation, monitoring, reporting, and con�servation of World Heritage sites is an important task, and it may have implications in the working processes of the World Heritage Committee. | Impacts | 29 - 29 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The Subsidiary Body for Scientific and Technological Advice (SBSTA) was requested to develop a structured five-year programme of work on impacts, vulnerability and adaptation. The draft list of activities (2006-2008) include methods and tools, data and observations, cli�mate modelling and downscaling, thresholds, socio-eco�nomic data, adaptation practices, research, adaptation platform and economic diversification. | Impacts | 29 - 29 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | 28 2 Predicting and managing the impacts of climate change on World Heritage PM_ClimateChange_22 UK 2/05/07 11:55 Page 28<br>UNESCO's Programme on Man and the Biosphere (MAB) The MAB Ecosystem based research focus includes research on sustainability, minimizing biodiversity loss and carbon sequestration issues. A number of priority ecosys�tems have been identified, including mountains, dry and arid lands, humid tropics, coastal zones and small islands as well as urban areas. Biosphere reserves have been used as a network for testing ways and means of minimizing biodiversity loss (2010 target), and addressing threats and opportunities posed by climate change. | Impacts | 29 - 30 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The high environmental sensitivity of coupled human�environment systems in mountain areas provides ideal circumstances for studying global change impacts. | Impacts | 30 - 30 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The UNESCO MAB Programme has therefore, together with the Mountain Research Initiative (MRI), launched a project on Global Change in Mountain Regions (GLOCHAMORE) which will attempt to address global change issues by reviewing the state of global change research in selected mountain biosphere reserves. These will then be used as pilot study areas for implementing activities that will help in assessing the impacts of global change on mountain environments and people. The bios�phere reserves selected to take part in the initial stages of the project include a number of World Heritage sites.14 Therefore, the World Heritage Convention and the UNESCO MAB Programme could cooperate and coor�dinate their activities in the field of developing and implementing monitoring, adaptation and mitigation options for World Heritage sites and Biosphere Reserves in mountain ecosystems. | Impacts | 30 - 30 |

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| UNESCO | Climate Change and World Heritage - UNESCO 2007 | In addition, there is considerable overlap and synergy between Biosphere Reserves and Ramsar sites (85), Biosphere Reserves and World Heritage sites (74) and all three (18) and these could specifically provide sustainable development approaches to improve carbon sequestra�tion, livelihoods and minimizing biodiversity loss. | Impacts | 30 - 30 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Ramsar Convention on Wetlands (1971) The attention to climate change issues is growing in the framework of the Ramsar Convention15 leading to the Conference of the Parties (COP8, Valencia 2002) and the documents prepared for this including 'Climate Change and Wetlands: Impacts, Adaptation and Mitigation.16 There are plans to update and to look specifically into addi�tional sources of information on wetland ecosystems and species including inland and coastal wetlands as well as peatlands. Resolution VIII.3 which was adopted by the contracting parties states '… that climate change is occurring and may substantially affect the ecological character of wetlands and their sustainable use' and '... | Impacts | 30 - 30 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The management challenges include addressing the impacts of multiple pressures where climate change is an added pressure. Wetlands are vulnerable to climate change and have limited adaptive capacity. Therefore innovative solutions are required. Management plans need to consider impacts from climate change and other pres�sures, have to minimize changes in hydrology from other human activities, to reduce non-climate pressures, to mon�itor the changes. Monitoring is essential to look at the effectiveness of adaptation options and steps to rectify any adverse effects should be part of the adaptive manage�ment strategy. A key limitation to implementing adapta�tion and mitigation options for wetlands is the lack of knowledge of wetland hydrology, functioning, their uses and past and present management. Pilot research projects at wetland World Heritage sites, which are also Ramsar sites, could help to fill this gap. | Impacts | 30 - 30 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Contracting Parties to the Ramsar Convention have to manage wetlands to increase their resilience to climate change and variability (extreme climatic events - floods and droughts) and promote wetland and watershed protection and restoration. The Ramsar Convention rec�ognizes that climate change impacts will vary between different wetland types and overall adaptation options are required. Again, the capacity of different regions to adapt to climate change depends upon their current and future states of socio-economic development and their exposure to climate stresses. In general, the potential for adaptation is more limited for developing countries, which are also projected to be more adversely affected by climate change. | Impacts | 30 - 30 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | 29 Predicting and managing the impacts of climate change on World Heritage 2 14. www.unesco.org/mab/mountains/home.htm. | Impacts | 30 - 30 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | 16. Ramsar, 2002. Climate Change and Wetlands: Impacts, Adaptation and Mitigation. Ramsar COP 8 DOC 11. Online: www.ramsar.org/cop8/cop8_doc_11_e.htm. 17. www.ramsar.org/world_heritage.htm. | Impacts | 30 - 30 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | PM_ClimateChange_22 UK 2/05/07 11:55 Page 29<br>30 2 Predicting and managing the impacts of climate change on World Heritage Convention on Biological Diversity (CBD) This Convention covers a wide range of issues related to the conservation and sustainable use of biodiversity. The impacts of climate change on biodiversity are already a major concern to the Convention on Biological Diversity. In 2000, the Conference of the Parties (COP) drew attention to the serious impacts of loss of biodiversity on terrestrial and marine ecosystems, and on people's livelihoods and requested the Convention's Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) to establish an ad hoc technical expert group. This group carried out an in-depth assessment of the inter-linkages between bio�diversity and climate change. There are significant oppor�tunities for mitigating climate change, and for adapting to climate change while enhancing the conservation of bio�diversity. The report also identified tools to help decision makers to assess impacts and make informed choices for mitigation and adaptation projects. | Impacts | 30 - 31 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Another expert group on biodiversity and adaptation to climate change was established, which undertook a detailed assessment. One of the main findings is that the ability of natural and managed ecosystems to adapt autonomously to climate change is insufficient to halt the rate of biodiversity loss and that adaptation towards increasing ecosystem resilience should be promoted. If one considers the example of species shifting ranges, although past changes in the global climate resulted in major shifts in species ranges, and biomes, these changes occurred in landscapes that were not as fragmented as today, and with fewer pressures from human activities. Therefore, one of the focus of the CBD includes the creation of corri�dors to protect biodiversity from the effects of climate change, and further, to recognize the important role that protected areas can play in mitigating some of the impacts of climate change. | Impacts | 31 - 31 |

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| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Networking ‘Natural and social systems of different regions have varied characteristics, resources and institutions, and are subject to varied pressures that give rise to differences in sensitivity and adaptive capacity’ (Intergovernmental Panel on Climate Change Technical Summary, p.44) This quotation indicates clearly the global impact of climate change. However the challenges need to be addressed at a regional level, with responsibility for adaptation being taken locally. | Impacts | 32 - 32 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The schematic below (Figure 1) illustrates the links between impacts, challenges and responses. It suggests that local managers will need to explore the potential for developing or adapting existing management plans and actions to respond to the climate change challenges. | Impacts | 32 - 32 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The environmental effects on cultural heritage such as climate change are transboundary. At the very least, regional networks need to be strengthened and focussed on climate change adaptation. UNESCO Regional Offices should encourage and support local initiatives, such as community awareness, emergency preparedness and maintenance training and considering to initiate partner�ships with research-led universities and institutions to ensure that research addresses the climate change prob�lems that cultural heritage is expected Research There is a need for more research on the effects of cli�mate change on both the physical heritage and the social and cultural processes that they are a part of. The Intergovernmental Panel on Climate Change (IPCC), set up in 1988, draws on the work of experts from around the world to provide objective information on climate change for policymakers. Their Assessment Reports provide the technical, scientific and socio-economic information on climate change, possible impacts and responses. Each report includes a Summary for Policy makers. The third Assessment Report was produced in 2001 and the fourth will be published in 2007. | Impacts | 32 - 32 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Working Group II of the IPCC is charged with assessing the impact, adaptation and vulnerability of societies to climate change. The report focuses on the effect of climate change on sectors, for example ecosystems, society and settlement and the effects regionally, usually on a continental scale. | Impacts | 32 - 32 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | 31 Predicting and managing the impacts of climate change on World Heritage 2 DEVELOP / ADAPT EXISTING MANAGEMENT PLANS / ACTIONS BY: Monitoring; Managing information; Preparing for threats Region 2 Challenges Region N Challenges Region 1 Challenges Local Managment Resources Local Managment Resources Local Managment Resources Global Impacts Figure 1: Schematic of the links among global, regional and local impacts and responses to climate change PM_ClimateChange_22 UK 2/05/07 11:55 Page 31<br>32 2 Predicting and managing the impacts of climate change on World Heritage There are several research and academic institutions and organizations worldwide18 that are engaged in research on climate change impacts. There is need for national heritage strategies to establish collaborative programmes with such bodies. | Impacts | 32 - 33 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Information management, communication, and building public and political support Strengthening of capacity building is important for dealing with effects of climate change as well as for good com�munication and awareness programmes. There is a need to ensure better gathering and analysis of information to identify changing conditions related to climate change. | Impacts | 33 - 33 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Not only should extreme events be documented but also short cycles of change that together can make significant changes to cultural heritage. Records of short cycle changes will gradually expand the notion of climate change impact on cultural heritage and enrich under�standing of this phenomenon. A more complex issue that will need underpinning by scientific research is that of doc�umenting cumulative processes to complement events�based data. | Impacts | 33 - 33 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Information needs to be disseminated on the following specific areas of need: • Climate change modelling and monitoring geared to cul�tural heritage; • Prediction of subsidence and heave caused by extreme weather; • Understanding of damage mechanisms and remediation due to extreme weather; • Understanding the effect of wind-driven rain at a local level which leads to severe damp penetration; • Understanding the effect of wind driven dust and pollu�tants at a local level leading to erosion and weathering; • Understanding the effect of new pest migration and infestations, eg. termites; • Understanding water resistance of building materials and techniques; • Assessment of the availability of stocks of renewable materials and the development of old technologies such as lime technology; • Environmental performance of historic buildings under extreme weather; • The interface between fragile and very robust materials. | Impacts | 33 - 33 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The notion that all cultural heritage can be saved when confronting climate change must be tackled through information on the meaning and fragility of cultural heritage including adaptation, loss and the notion of abandonment in the face of extreme weather. | Impacts | 33 - 33 |

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| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Communication and building public and political  support  Mobilizing public and political support for climate change  adaptation and mitigation inside and outside World  Heritage sites is essential. This has to range from local to  regional and global approaches and involve a variety of  measures: workshops, exhibitions and expositions, media  campaigns, audio-visual material and popular publications  which link the global phenomenon of climate change to  the local and regional context. Most likely, maximum sup�port is further gained through linking local and regional  impacts to individual actions and vice versa. For example,  simple and straight-forward ways of communicating the  impacts and implications of climate change in a local and  regional context raised considerable public and political  awareness in the Cape Floral Region in South Africa (see  Box 2 on p.19) – with subsequent benefits for research,  decision-making, planning and management.19  One of the requests of the Committee in its Decision  29 COM 7B.a related to the use of the World Heritage  network is 'to demonstrate management actions that  need to be taken to meet [climate change] threats both  within the properties and in their wider context'. To  address this aspect of the Decision, it is proposed that spe�cific World Heritage sites be used as demonstration mod�els for countries and other stakeholders to design  adaptation and mitigation strategies for World Heritage sites facing climate change challenges. Communication on  this issue could occur at two levels. First, at the local and  regional level where World Heritage sites are used as  anchors to build site-based and national awareness and  strategies (bringing together NGO's, academics, and other  field-based researchers). At the second, global level, the  newly developed strategies are disseminated to the World  Heritage Committee, States Parties and other stakeholders  through NGO networks (Advisory Bodies and other con�servation NGOs), academic networks and UN bodies. | Impacts | 33 - 33 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Another request of the World Heritage Committee at its  29th session (Durban, 2005) concerned the dissemination  of information on the effects of climate change on World  Heritage sites to 'reach the public at large, in order to  mobilize political support for activities against climate  change and to safeguard in this way the livelihood of the  poorest people of our planet.' As World Heritage is tied to  some of the most recognizable, renowned, iconic, and  cherished destinations around the world, it is suggested to  use some of these places to convey information on the  direct impacts of climate change in order to reach the pub�lic and gain its support for actions. Here as well, strategies  and activities should be built at different levels. Developing  case studies on the impacts of climate change on a few  iconic World Heritage sites would allow drawing a lot of  attention from the public, the media and the policy mak�ers. The selection of sites concerned by such case studies  would obviously require further discussion with States  Parties and within the World Heritage Committee. | Impacts | 34 - 34 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | • Observations of damage due to climate change. | Impacts | 34 - 34 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Local communities should be closely involved in the  processes of investigation of the impacts of climate change  and the development of adaptation strategies. The strong  links between cultural and natural heritage could also be  reflected in these case studies. These case studies should  also be the opportunity to illustrate how adaptation meas�ures could be developed to avoid the general feeling of dis�couragement of the public in the face of climate change. | Impacts | 34 - 34 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Vulnerability assessment  Natural heritage  Climate change will impact a wide range of biomes. As far  as terrestrial biodiversity is concerned, the range of poten�tial impacts includes:  Assess vulnerability of World Heritage properties and  develop strategies for those at most risk  The vulnerability of natural World Heritage sites is a func�tion of their exposure, sensitivity and adaptive capacity to  the present and potential future impacts of climate  change. The general objective of vulnerability assessment  is to inform decision-makers of specific options for allevi�ating and adapting to the impacts of global change.20  The strong variation in vulnerability by location requires a  site-based analysis with simultaneous links to other sites  and scales of analysis.21 This can be applied to natural  World Heritage sites since World Heritage crosses all  scales, with individual sites of varying size embedded in a  variety of different terrestrial and marine ecosystems  around the world. State-of-the-art vulnerability assess�ments provide a framework for assessing the vulnerabil�ity of natural World Heritage sites based on both  scientific and stakeholder-specific assessment of the  exposure, sensitivity and adaptive capacity to climate  changes. The promotion of these assessments by the  World Heritage Convention will have a major impact at  national and international levels. | Impacts | 34 - 34 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | 33  Predicting and managing the impacts of climate change on World Heritage 2  20. Schröter et al., 2005. Assessing vulnerabilities to the effects of global change: an eight step approach. Mitigation and Adaptation  Strategies for Global Change 10, 573-596. | Impacts | 34 - 34 |

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| UNESCO | Climate Change and World Heritage - UNESCO 2007 | PM_ClimateChange_22 UK 2/05/07 11:55 Page 33<br>34 2 Predicting and managing the impacts of climate change on World Heritage A two-pronged approach is required: first, the vulnerabil�ity of natural World Heritage sites, which are particularly at risk, should be assessed by the States Parties and specific site-level mitigation and adaptation strategies should be designed and implemented in partnership with relevant stakeholders. Second, States Parties and site managers need to look beyond the individual site level and develop and implement regional and/or transboundary mitigation and adaptation strategies that reduce the vulnerability of natural World Heritage sites in a larger landscape or seascape context. Natural World Heritage sites must be seen as core sites within functioning regional networks of protected areas, conservation corridors and stepping stones. 'Healthy' World Heritage sites can contribute con�siderably to 'healthy' landscapes and seascapes that are better able to buffer climate change impacts. The World Heritage Centre and Advisory Bodies to the World Heritage Convention should encourage States Parties and site managers, in collaboration with relevant academic and research institutions, to accomplish these tasks and make available their knowledge and experience in the field of climate change adaptation and mitigation. | Impacts | 34 - 35 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | An eight-step approach has been developed to guide vul�nerability assessments of coupled human-environment systems (see Box 9). This approach could be adopted easily for World Heritage sites and can also be used to guide future work on vulnerability under the World Heritage Convention. Most importantly, vulnerability assessments should not look at climate change impacts in isolation, but should rather assess the vulnerability of World Heritage sites to global change impacts in general due to the many interactions involved. | Impacts | 35 - 35 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Assess future climate change scenarios through appropriate tools and guidelines A comprehensive set of technical guidelines to assess cli�mate change impacts and response strategies in general is available from the Intergovernmental Panel on Climate Change,24,25 and has been reviewed from a coastal per�spective.26 Climate change impacts and response strate�gies have been recently discussed in detail for islands.27 22. For a detailed discussion see Schröter et al. (2005, Assessing vul�nerabilities to the effects of global change: an eight step approach. Mitigation and Adaptation Strategies for Global Change 10, 573-596). According to them, for vulnerability assessments, the role of numerical modelling is the projection of future states of a system. Here, steps 1-3 take place prior to modelling, whereas steps 4-8 take place as part of the modelling and modelling refinement process. | Impacts | 35 - 35 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | 25 Parry & Carter, 1998. Climate Impact and Adaptation Assessment: a Guide to the IPCC Approach. Earthscan, London. | Impacts | 35 - 35 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | PM_ClimateChange_22 UK 2/05/07 11:55 Page 34<br>For natural systems28 and protected areas,29,30 initial les�sons learnt and guidelines are available, but need to be adjusted for natural World Heritage properties. Using these guidelines for assessing regional and local levels impacts remains a challenge; therefore the World Heritage Convention should promote the development and testing of available guidelines based on existing experience such as WWF's 'Regional Biodiversity Impact Assessments for climate change: A guide for protected�areas managers' as well as the results from IUCN's projects in Nepal (Sagarmatha National Park) and Peru (Tambopata National Park and Inambari Biosphere Reserve) where a computer-based Decision Support System (DSS) has been developed to assess ecosystem changes over time in response to a number of social and environmental factors. | Impacts | 35 - 36 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Risk and vulnerability maps No one can afford to wait for all the research to be com�pleted for guidance on the management of cultural her�itage under climate change conditions. It will be important to produce risk and vulnerability maps of World Heritage regions and sub-regions which overlay climate data and heritage site locations so that an overview of the risks to different aspects of cultural heritage can be obtained. Using this information, detailed adaptation strategies can then be developed. | Impacts | 36 - 36 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | It is important for the sustainability of cultural heritage in the face of climate change for communities to interact across the generations by documenting past climate events and their impact on cultural heritage. This will enable the present generation to learn from the past and to pass knowledge of the specific culture of the place and its adaptive capability to future generations. | Impacts | 36 - 36 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | At the same time, there should be a focus on professional monitoring strategies. Remote sensing such as the use of satellite technology, non-destructive techniques, bio�sensing to assess biological damage to materials and the use of simulation tools to predict the impact of climate change on the behaviour of cultural heritage materials are needed. Specific high-tech systems and products could include: • Instruments for monitoring environment/component/ system failure. | Impacts | 36 - 36 |

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| UNESCO | Climate Change and World Heritage - UNESCO 2007 | 35 Predicting and managing the impacts of climate change on World Heritage 2 28 Hansen et al., 2003. Buying Time: a User's Manual for Building Resistance and Resilience to Climate Change in Natural Systems. | Impacts | 36 - 36 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Applying adaptive management responses In many areas, promising management responses are being developed and implemented already. A number of different solutions to specific problems posed by climate change are available. Technical solutions are available in some cases, but they might not be affordable or feasible in all cases, and they might also be controversial when it comes to application to World Heritage sites, with poten�tial impacts on the conditions of integrity. For example, in some coastal areas, reinforcing dykes and drains to deal with rising sea level have been considered as options, whereas in other coastal areas, management has favoured a planned retreat of settlements from low-lying areas. The water level of some wetlands can be con�trolled by regulating water inflow or outflow with dams, but increasing temperatures and decreasing precipitation will in many areas result in stiffer competition between nature and people for water. | Impacts | 37 - 37 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | BOX 10 Reducing the risk of GLOF in the Sagarmatha National Park (Nepal)33 The Tsho Rolpa glacial lake project is one of the most significant examples of collaborative anticipatory plan�ning by the government, donors, and experts in GLOF mitigation. Tsho Rolpa was estimated to store approxi�mately 90-100 million m3, a hazard that called for urgent attention. A 150-meter tall moraine dam held the lake, which if breached, could cause a GLOF event in which a third or more of the lake could flood down�stream. This threat led to a collaborative action by the Nepalese Government and the Netherlands Development Agency, with the technical assistance of Reynolds Geo-Sciences Ltd., supported by the United Kingdom Department for International Development. | Impacts | 37 - 37 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | To mitigate this risk, an expert group recommended lowering the lake three meters by cutting an open channel in the moraine. In addition, a gate was con�structed to allow water to be released as necessary. | Impacts | 37 - 37 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The goal of lowering the lake level was achieved by June 2002, which reduced the risk of a GLOF by 20%. | Impacts | 37 - 37 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The complete prevention of a GLOF at Tsho Rolpa necessitates further reducing the lake water, perhaps by as much as 17 meters. Expert groups are now undertaking further studies, but it is obvious that the cost of mitigating GLOF risks is substantial and time consuming. The cost, however, is much less than the potential damage that would be caused by an actual event in terms of lost lives, communities, development setbacks, and energy generation. | Impacts | 37 - 37 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | 36 2 Predicting and managing the impacts of climate change on World Heritage 31. Barber et al. (eds.), 2004. Securing Protected Areas in the Face of Global Change: Issues and Strategies. A Report by the Ecosystems, Protected Areas, and People Project. IUCN, Gland and Cambridge. | Impacts | 37 - 37 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | From this box it is particularly important to stress that realistic response strategies cannot be planned without taking into account the impacts from other non-climatic stresses on natural ecosystems, such as habitat frag�mentation and loss, alien and invasive species, over�exploitation, pollution, sedimentation, etc which severely impede natural adaptation and mitigation strategies. Hence, there is a need for the World Heritage Convention to continue enhancing its work in assessing the management and conditions of integrity of World Heritage properties, both through reactive monitoring and periodic reporting. | Impacts | 38 - 38 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Cultural heritage While it may be possible to adapt to climate change by moving moveable cultural heritage away from a site, doing so could have an overall negative effect on the value of a site. Therefore, despite the fact that World Heritage sites may be subject to more severe changes in their climatic, social or cultural environment, the fact that they are by their nature immoveable means that adapta�tion has to take place on site. | Impacts | 38 - 38 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Although the relative importance of climatic and anthro�pogenic factors as a cause of desertification remains unresolved, evidence shows that an increase in dust storms would result in damage to settlements and infra�structure, and will affect human health and population migration. Thus, the impact on cultural heritage could range from erosion of physical structures to the break-up of the societies and communities supporting World Heritage sites or even to abandonment, with the even�tual loss of cultural memory. | Impacts | 38 - 38 |

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| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Monitoring and adaptative management  Monitoring the impact of climate change is obviously an  important issue, as was mentioned in the sections on  'research' and 'information management'. But the care�ful monitoring of adaptive management measures must  also be planned in the context of climate change and  World Heritage. | Impacts | 38 - 38 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Monitoring climate, climate impacts and management  responses is critical. Only then will one be able to tell  which responses do work and which do not. But few of  the existing monitoring measures are tailored to issues  relevant to climate change adaptation and mitigation of  37  Predicting and managing the impacts of climate change on World Heritage 2  34. Shafer, 1999. National park and reserve planning to protect bio�logical diversity: some basic elements. Landscape and Urban  Planning 44, 123-153. | Impacts | 38 - 38 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | PM_ClimateChange_22 UK 2/05/07 11:55 Page 37<br>38  2 Predicting and managing the impacts of climate change on World Heritage  protected areas. Capacity-building, for example in rela�tion to fire and risk management, is underway in many  areas, sometimes already linked to the additional prob�lems posed or accelerated by climate change. In many  cases, adaptive management, if implemented properly,  should help to buffer climate change impacts. Adaptive  management is a systematic process of continually  improving policies and practices by learning from the  results of previous actions. | Impacts | 38 - 39 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Risk preparedness  A strategy for dealing with disasters resulting from cli�mate change should be linked with the larger disaster  risk-planning and strategy efforts including the 'Strategy  for Reducing Risks from Disaster at World Heritage  Properties' prepared by ICOMOS, ICCROM, and the World Heritage Centre for consideration by the World  Heritage Committee at the present 30th session (WHC-  06/30.COM/7.2). The rationale for this strategy follows  the priorities for action of the Hyogo Framework for  Action 2005-2015:  • Ensure that disaster risk reduction is a national and a local priority with a strong institutional basis for imple�mentation by strengthening support within relevant  global, regional, national and local institutions. | Impacts | 39 - 39 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | • Identify, assess, monitor disaster risks, and enhance  early warning at World Heritage properties. | Impacts | 39 - 39 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | • Reduce underlying risks factors. | Impacts | 39 - 39 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Note: The implication of this process response to climate change is that more needs to be done on monitoring, research and mainte�nance for cultural heritage than the natural heritage which has already recognized the impact of climate change on World Heritage  sites. | Impacts | 39 - 39 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | PM_ClimateChange_22 UK 2/05/07 11:55 Page 38<br>39  A strategy to assist States  Parties to implement   appropriate management   responses  Cape Floral Region, South Africa   © UNESCO / Norman Guy Palmer  3  PM_ClimateChange_22 UK 2/05/07 11:55 Page 39<br>The strategy outlined below has been developed  after a detailed analysis of the various issues elabo�rated in the report on 'Predicting and managing the  effects of climate change on World Heritage'  (Section 2). Detailed guidance on each aspect of the  strategy is available in that report. | Impacts | 39 - 41 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Preamble: Objectives and requirements  The potential impacts of climate change range from  physical, to social and cultural aspects. As far as natural  heritage is concerned, the vast majority of biomes may be  adversely impacted by the effects of climate change. | Impacts | 41 - 41 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Experience and lessons learned on addressing climate  change impacts stress the need for using a number of  management responses at national and local levels. The  World Heritage Convention provides an opportunity to  develop strategies to implement relevant actions in respect  of cultural and natural heritage properties threatened by  climate change. Given the complexity of this issue, States  Parties may request guidance from the World Heritage  Committee to implement appropriate management  responses to face the threats posed by climate change on  their natural and cultural properties inscribed on the World  Heritage List. | Impacts | 41 - 41 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Therefore, the main objective of this strategy is to review  the main topics that should be considered when preparing  to implement preventive and/or corrective management  responses to deal with the adverse impacts of climate  change. | Impacts | 41 - 41 |

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| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Conservation is the management of change, and climate change is one of the most significant global challenges facing society and the environment today. The actions that need to be taken to safeguard heritage are threefold: a. Preventive actions: monitoring, reporting and mitiga�tion of climate change effects through environmentally sound choices and decisions at a range of levels: indi�vidual, community, institutional and corporate. | Impacts | 41 - 41 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Therefore, whereas climate change impacts will differ for World Heritage of natural and cultural types, the proposed strategy should address both types of properties jointly. | Impacts | 41 - 41 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Lastly, climate change is one risk among a number of chal�lenges facing World Heritage sites. This threat should be considered in the broader context of the conservation of these sites. | Impacts | 41 - 41 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Preventive actions Monitoring and reporting* a. Global level actions (World Heritage Convention): i. Include climate change impacts within World Heritage periodic reporting and reactive monitoring, and other monitoring processes in order to enable global assessment. | Impacts | 41 - 41 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | b. Regional (cross-State Party) / thematic actions: i. Include climate change impacts within any World Heritage periodic reporting and reactive monitoring processes for existing and future World Heritage properties in order to enable regional / thematic assessment. | Impacts | 41 - 41 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | ii. Reduce non-climatic stress factors on the site to enhance its resilience to climate change impacts. | Impacts | 41 - 41 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Mitigation** The UNFCCC is the UN instrument through which mitiga�tion strategies at the global and States Parties level is being addressed. However, the World Heritage community could participate in climate change mitigation at the level of the World Heritage through: a. Global level actions (World Heritage Convention): i. Provide information to IPCC and UNFCCC on the impacts of climate change on World Heritage sites to assist them in tailoring mitigation strategies. | Impacts | 41 - 41 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Corrective actions: Management, adapta�tion, and risk management* The States Parties need to be aware of the risks posed by climate change and that clear short term actions are needed and possible: a. Global level actions (World Heritage Convention): i. Include climate change as an additional source of stress in the Strategy for reducing risks from disasters at World Heritage properties which is presented as a separate working Document (WHC-06/30.COM/7.2), including approaches to vulnerability assessment. | Impacts | 42 - 42 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | ii. Request new and existing sites to integrate climate change issues into new and revised management plans (as appropriate) including: risk preparedness, adaptive design and management planning. | Impacts | 42 - 42 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | c. State Party / site-level actions: i. Conduct climate change vulnerability analysis, risk assessment, adaptation, and develop appropriate management plans. | Impacts | 42 - 42 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | ii. Consider climate change as well as other challenges when developing nominations - such as by ensuring landscape connectivity, defining appropriate bound�aries and buffer zones, in order to achieve better resistance and resilience to climate change impacts. | Impacts | 42 - 42 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Communication, education, training, capacity build�ing, raising awareness, and sharing good practices, information, and knowledge*** a. Global level actions (World Heritage Convention): i. Inform the UNFCCC of the impacts of climate change on World Heritage in order to include these aspects into their guidelines for national communi�cations. | Impacts | 42 - 42 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | ii. Ensure that climate change impacts and environ�mental education are integrated in general training programmes (of the World Heritage Centre and Advisory Bodies) by preparing training material and running specific courses on the impacts of climate change. | Impacts | 42 - 42 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | 41 Strategy to assist States Parties to implement appropriate management responses 3 * See pages: - 30 (Designing management plans accounting for the issue of climate change), - 33 (Vulnerability assessment), - 36 (Adaptation), - 37 (Monitoring and adaptative management), - 38 (Risk preparedness). | Impacts | 42 - 42 |

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| UNESCO | Climate Change and World Heritage - UNESCO 2007 | PM_ClimateChange_22 UK 2/05/07 11:55 Page 41<br>42 3 Strategy to assist States Parties to implement appropriate management responses iv. Develop communication strategies taking advantage of the World Heritage global network to inform the public and policy makers about the impacts of cli�mate change on World Heritage sites and build pub�lic and political support for actions to address the situation. | Impacts | 42 - 43 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | ii. Ensure that training courses on risk assessments, reporting, adaptation and monitoring are coordi�nated with other international institutions, Advisory Bodies, and secretariats of other conventions. | Impacts | 43 - 43 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | c. State Party / site level actions: i. Provide information to decision-makers, stakehold�ers, local communities, users of the sites, site man�agers, and other heritage specialists about the impacts of climate change on sites, management responses, possible assistance, existing networks, specific training, courses, and long- distance learn�ing opportunities. | Impacts | 43 - 43 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | a. Global level actions (World Heritage Convention): i. Establish cooperation with IPCC to assess the impacts of climate change on World Heritage; inves�tigate opportunities to mention issues related to World Heritage in future climate change assessment reports. | Impacts | 43 - 43 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | iii.Develop coordinated approach to research on the impacts of climate change on cultural World Heritage, including impacts as result of changes in society (i.e. movement of peoples, displacement of communities, their practices, and their relation with their heritage). | Impacts | 43 - 43 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | b. Regional (cross-State Party) / thematic actions: i. Promote the development of risk and vulnerability maps for regions and sub-regions which overlay climate data and World Heritage site locations. | Impacts | 43 - 43 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | c. State Party / site level actions: i. Collect and document information on the impacts of past and current climate change on World Heritage sites. | Impacts | 43 - 43 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | ii. Review previous periodic reports, as it could lead to the identification of past impacts of climate change on World Heritage, which may not have been attrib�uted to climate change at the time of the original report. | Impacts | 43 - 43 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Legal issues After having considered the range of actions to be under�taken in the framework of the management of climate change impacts on World Heritage, the group of experts considered that when the Operational Guidelines are next revised, the possibility of including climate change related aspects could be explored. | Impacts | 43 - 43 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | PM_ClimateChange_22 UK 2/05/07 11:55 Page 42<br>43 Conclusion and steps ahead Huascarán National Park, Peru © Renzo Uccelli Appendices PM_ClimateChange_22 UK 2/05/07 11:55 Page 43 While endorsing the Report and Strategy at its 30th session, the World Heritage Committee desired that these documents be disseminated widely to the World Heritage community and the public at large. It is hoped that this publication will serve that broader purpose, together with another publication recently brought out by the Centre, which is a compilation of case studies highlighting the impacts of climate change on World Heritage properties, Case Studies on World Heritage and Climate Change, UNESCO, March, 2007. | Impacts | 43 - 45 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Further, at the behest of the Committee, a draft policy document has been prepared on the subject for consider�ation at its 31st session (23 June – 2 July 2007) and adop�tion by the General Assembly of States Parties to the Convention later in the year. Relevant elements of the Strategy are also being mainstreamed into various processes of the Convention, including nominations, reac�tive monitoring, periodic reporting, international assis�tance, capacity building, as well as into the strategy for reducing risks from disasters at World Heritage properties. | Impacts | 45 - 45 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | While opportunities are being explored with donors for implementing pilot projects on vulnerability assessment and adaptation at some World Heritage sites, the impacts of climate change can be effectively addressed only when the strategy outlined in this publication is applied at the field level. It is for this purpose that the World Heritage Committee has requested States Parties and all partners concerned to implement this strategy to protect the out�standing universal values, integrity and authenticity of World Heritage sites from the adverse effects of climate change, to the extent possible and within the available resources. | Impacts | 45 - 45 |

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| UNESCO | Climate Change and World Heritage - UNESCO 2007 | 4 Conclusion and steps ahead 44 PM_ClimateChange_22 UK 2/05/07 11:55 Page 44 45 Chinguetti mosque, Mauritania © UNESCO / Galy Bernard Appendices PM_ClimateChange_22 UK 2/05/07 11:55 Page 45 Expert Meeting of the World Heritage Convention on the Impacts of Climate Change on World Heritage The World Heritage Committee at its 29th session (Durban, 2005) requested the World Heritage Centre (WHC), in collaboration with the Advisory Bodies, inter�ested States Parties and petitioners who had drawn the attention of the Committee to this issue, to convene a broad working group of experts on the impacts of climate change on World Heritage (Decision 29 COM 7B.a). The Committee took this decision noting 'that the impacts of climate change are affecting many and are likely to affect many more World Heritage properties, both natural and cultural in the years to come'. The Committee requested the broad working group of experts to: • review the nature and scale of the risks posed to World Heritage properties arising specifically from climate change; • jointly develop a strategy to assist States Parties to imple�ment appropriate management responses; and • prepare a joint report on 'Predicting and managing the effects of climate change on World Heritage' to be examined by the Committee at its 30th session (Vilnius, 2006). | Impacts | 45 - 47 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The meeting was prepared after a rigorous and extensive consultation process between a core group, comprising the World Heritage Centre, the Advisory Bodies, and experts from the State Party of the United Kingdom. The United Nations Foundation (UNF) provided crucial financial support to the World Heritage Centre to enable some of the preparatory and follow-up actions. The agenda, list of participants and background documents for the expert meeting were prepared through collaboration between the core group. A background document compiled information on the assessment and management of the impacts of climate change in the context of World Heritage. A number of case studies on the impacts of climate change on specific World Heritage sites were also submitted by many experts for consideration by the participants to the meeting. | Impacts | 47 - 47 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Presentations to the plenary: The climate change activ�ities of relevant international conventions were presented to the plenary. A statement from the CBD was read on behalf of Mr Ahmed Djoghlaf (Executive Secretary of the CBD). Ms Habiba Gitay (World Resources Institute) pre�sented the activities of the Ramsar Convention, Mr Festus Luboyera (UNFCCC) presented the UN Framework Convention on Climate Change, and Mr Natarajan Ishwaran (UNESCO) introduced the MAB Programme of UNESCO. A keynote speech on the impacts of climate change for cultural World Heritage was given by Ms May Cassar (University College London), and ICOMOS' net�work approach on climate change and heritage structures, sites and areas was presented by Mr Dinu Bumbaru (ICOMOS). Case studies on the impacts of climate change on five natural and cultural World Heritage sites were also described by relevant experts. The plenary sessions were concluded by a presentation of Ms Erika Harms (UNF) on raising public awareness and building political support. | Impacts | 47 - 47 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Working sessions: The group of experts worked sepa�rately in two concurrent sessions on cultural and natural heritage issues to review the draft framework strategy to assist States Parties on implementing appropriate man�agement responses; and to review the draft background document prepared in advance with the aim of producing a comprehensive report on 'Predicting and managing the effects of climate change on World Heritage'. | Impacts | 47 - 47 |

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| UNESCO | Climate Change and World Heritage - UNESCO 2007 | PM_ClimateChange_22 UK 2/05/07 11:55 Page 46<br>47 Appendices 16 March 2006 09.00 Registration 09.15 – 10.00 Session 1 Opening Session Chair: Mr Francesco Bandarin (Director of the WHC) Rapporteur: Dr Mechtild Rössler (Chief Europe and North America WHC) Welcome Mr Francesco Bandarin (Director of the WHC) Opening remarks Ms Ina Marciulionyte (Chairperson of the WH Committee) Keynote address on 'Implications of climate change Mr Martin Parry for World Heritage sites' (Co-chair of WGII of the IPCC) Overview of the decision of the World Heritage Mr Kishore Rao Committee, the agenda, the objectives of the meeting, (Deputy Director of the WHC) the strategic requirements and report on the results of the climate change survey submitted to States Parties 10.00 – 10.30 Coffee break 10.30 – 13.00 Session 2 Natural Heritage Chair: Mr David Sheppard (Head of IUCN's Programme on Protected Areas) Rapporteur: Mr Guy Debonnet (WHC) 2-5 min Convention on Biological Diversity Statement on behalf of Mr Ahmed Djoghlaf (Executive Secretary of the CBD) 10 min Key issues for climate change and wetlands Dr Habiba Gitay (on behalf of Ramsar Convention) (World Resources Institute) 10 min United Nations Framework Convention Mr Festus Luboyera on Climate Change (UNFCCC Secretariat) 10 min UNESCO Man and the Biosphere Programme Dr Natarajan Ishwaran (UNESCO, Division of Ecological and Earth Sciences) 35 min Case Study 1: 'Towards conservation strategies for Mr Guy Midgley and Mr Bastian Bomhard future climate change in the Cape Floral Region [presenting author] (South African National Protected Areas (South Africa)' Biodiversity Institute) 35 min Case Study 2: The Great Barrier Reef (Australia) Dr Greg Terrill (Australian Department of Environment and Heritage) 35 min Case Study 3: 'Risks, points of view and conflicts Mr Pablo Dourojeani in the Huascarán NP World Heritage site (Peru) due (The Mountain Institute, Peru) to climate change' 13.00 – 14.00 Lunch Break Agenda of the Expert Meeting on Climate Change and World Heritage Special Expert Meeting of the World Heritage Convention: Climate Change and World Heritage UNESCO HQ, Paris (France) 16-17 March, 2006 16 March 2006 ... | Impacts | 47 - 48 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | PM_ClimateChange_22 UK 2/05/07 11:55 Page 47<br>48 Appendices 14.00 – 16.00 Session 3 Cultural Heritage Chair: Ms Mandy Barrie (UK Department for Culture Media and Sport) Rapporteur: Mr Joseph King (ICCROM) 15 min Climate change and cultural heritage Prof. May Cassar (University College London, UK) 15 min ICOMOS' network approach on climate change Mr Dinu Bumbaru (ICOMOS) and heritage structures, sites and areas 35min Case Study 4: 'Impact of climate change on the Mr Ali Ould Sidi (Mission culturelle de World Heritage sites of Timbuktu (Mali)' Tombouctou, Mali) 35min Case Study 5: 'Evident threats of climate change to Mr Douglas Olynyk (Yukon Territorial cultural resources within existing and potential Government & ICOMOS Canada) World Heritage sites in Yukon Territory, Canada' 16.00 – 16.30 Coffee Break 16.30 – 17.00 Session 4 Awareness, communication and support Chair: Mr Paul Hoffman (US National Park Service) Rapporteur: Ms Regina Durighello (ICOMOS) 16.30 – 17.00 Raising public awareness and building support for 'Climate change and World Heritage' Ms Erika Harms (United Nations Foundation) 17.00 – 18.00 Summary of key issues and discussion on Chairs of sessions 2 and 3 previous presentations 19.00 Cocktail hosted by the World Heritage Centre 17 March 2006 09.00 Plenary briefing on working groups procedure Mr Kishore Rao (Deputy Director of the WHC) 09.15 – 12.30 Concurrent Natural/Cultural Sessions Session 5.1 Cultural Heritage Review framework strategy and expected outputs. | Impacts | 48 - 49 |

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| UNESCO | Climate Change and World Heritage - UNESCO 2007 | PM_ClimateChange_22 UK 2/05/07 11:55 Page 49 50 Appendices Decision 29 COM 7B.a of the World Heritage Committee, 29th session (2005) The World Heritage Committee, 1. Having examined Document WHC-05/29.COM/7B.Rev and the draft Decision 29 COM 7B.a.Rev, 2. Recognizing the work being undertaken within the framework of the UN Convention on Climate Change (UNFCC), and the need for a proper coor�dination of such work with the activities under the Convention, 3. Takes note of the four petitions seeking to have Sagarmatha National Park (Nepal), Huascaran National Park (Peru), the Great Barrier Reef (Australia) and the Belize Barrier Reef Reserve System (Belize) included on the List of World Heritage in Danger, 4. Appreciates the genuine concerns raised by the various organizations and individuals supporting these petitions relating to threats to natural World Heritage properties that are or may be the result of climate change, 5. Further notes that the impacts of climate change are affecting many and are likely to affect many more World Heritage properties, both natural and cultural in the years to come, 6. Encourages all States Parties to seriously consider the potential impacts of climate change within their management planning, in particular with monitoring, and risk preparedness strategies, and to take early action in response to these potential impacts; 7. Requests the World Heritage Centre, in collabora�tion with the Advisory Bodies, interested States Parties and petitioners, to establish a broad work�ing group of experts to: a) review the nature and scale of the risks posed to World Heritage proper�ties arising specifically from Climate Change; and b) jointly develop a strategy to assist States Parties to implement appropriate management responses, 8. Welcomes the offer by the State Party of the United Kingdom to host a meeting of such work�ing group of experts, 9. Requests that the working group of experts, in consultation with the World Heritage Centre, the Advisory Bodies and other relevant UN bodies, prepare a joint report on 'Predicting and managing the effects of climate change on World Heritage', to be examined by the Committee at its 30th session (2006), 10. Strongly encourages States Parties and the Advisory Bodies to use the network of World Heritage properties to highlight the threats posed by climate change to natural and cultural heritage, start identifying the properties under most serious threats, and also use the network to demonstrate management actions that need to be taken to meet such threats, both within the properties and in their wider context, 11. Also encourages UNESCO to do its utmost to ensure that the results about climate change affecting World Heritage sites reach the public at large, in order to mobilize political support for activities against climate change and to safeguard in this way the livelihood of the poorest people of our planet | Impacts | 50 - 51 |

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| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Decision 30 COM 7.1 of the World Heritage Committee, 30th session (2006) The World Heritage Committee, 1. Having examined Document WHC-06/30.COM/7.1, 2. Recalling Decision 29 COM 7B.a adopted at its 29th session (Durban, 2005), 3. Also recalling the submission in 2005 of four peti�tions by civil society and non-governmental organ�izations on the impacts of Climate Change on World Heritage properties, complemented by an additional petition in February 2006, 4. Further recalling paragraph 44 of the Operational Guidelines, 5. Thanks the Government of the United Kingdom for having funded the meeting of experts, which took place on the 16th and 17th of March 2006 at UNESCO Headquarters in Paris, and also thanks the United Nations Foundation for its support, as well as all the experts who contributed to the meeting, 6. Endorses the 'Strategy to assist States Parties to implement appropriate management responses' described in Document WHC-06/30.COM/7.1, and requests the Director of the World Heritage Centre to lead the implementation of the 'Global PM_ClimateChange_22 UK 2/05/07 11:55 Page 50<br>51 Appendices level actions' described in the Strategy through extrabudgetary funding and also takes note of the report on 'Predicting and managing the impacts of Climate Change on World Heritage', 7. Encourages UNESCO, including the World Heritage Centre, and the Advisory Bodies to dis�seminate widely this strategy, the report, and any other related publications through appropriate means to the World Heritage community and the broader public, 8. Requests States Parties and all partners concerned to implement this strategy to protect the Outstanding Universal Value, integrity and authen�ticity of World Heritage sites from the adverse effects of Climate Change, to the extent possible and within the available resources, recognizing that there are other international instruments for coordinating the response to this challenge, 9. Invites States Parties, the World Heritage Centre and the Advisory Bodies to build on existing Conventions and programmes listed in Annex 4 of Document WHC-06/30.COM/7.1, in accordance with their mandates and as appropriate, in their implementation of Climate Change related activities, 10. Also requests States Parties, the World Heritage Centre, and the Advisory Bodies to seek ways to integrate, to the extent possible and within the available resources, this strategy into all the rele�vant processes of the World Heritage Convention including: nominations, reactive monitoring, peri�odic reporting, international assistance, capacity building, other training programmes, as well as with the 'Strategy for reducing risks from disasters at World Heritage properties' (WHC- 06/30.COM/7.2), 11. Strongly encourages the World Heritage Centre and the Advisory Bodies in collaboration with States Parties and other relevant partners to develop proposals for the implementation of pilot projects at specific World Heritage properties espe�cially in developing countries, with a balance between natural and cultural properties as well as appropriate regional proposals, with the objective of developing best practices for implementing this Strategy including preventive actions, corrective actions and sharing knowledge, and recommends to the international donor community to support the implementation of such pilot projects, 12. Further requests the States Parties and the World Heritage Centre to work with the Intergovernmental Panel on Climate Change (IPCC), with the objective of including a specific chapter on World Heritage in future IPCC assessment reports, 13. Requests the World Heritage Centre to prepare a policy document on the impacts of climate change on World Heritage properties involving consulta�tions with relevant climate change experts and practitioners of | Impacts | 51 - 52 |
| UNESCO | Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | Impacts of Climate Change on World Heritage Coral Reefs A First Global Scientific Assessment World Heritage Convention United Nations Educational, Scientiffc and Cultural Organization • WORLD HERITAGE • PATRIMOINE MONDIAL • PATRIMONIO MUNDIAL Coordinating Lead Authors: Scott F. Heron1,2, C. Mark Eakin1 , Fanny Douvere3 Contributing Authors*: Kristen Anderson4 , Jon C. Day4 , Erick Geiger1,2, Ove Hoegh-Guldberg5 , Ruben van Hooidonk6,7, Terry Hughes4 , Paul Marshall8,9, David Obura10 *listed in alphabetical order Suggested citation: Heron et al. 2017. Impacts of Climate Change on World Heritage Coral Reefs : A First Global Scientific Assessment. Paris, UNESCO World Heritage Centre. | Impacts | 1 - 2 |
| UNESCO | Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | This assessment aims to make available the most current knowledge regarding the impacts of climate change on World Heritage properties as requested by the World Heritage Committee Decision 40 COM 7 (Istanbul/UNESCO, 2016). | Impacts | 2 - 2 |
| UNESCO | Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | Coral reefs are ecologically and economically important ecosystems found across the world's tropical and sub-tropical oceans. Despite covering less than 0.1% of the ocean floor, reefs host more than one quarter of all marine fish species (in addition to many other marine animals)1,2. They are the most inherently biodiverse ecosystems in the ocean – comparable to rainforests on land. These 'Rainforests of the Sea' provide social, economic and cultural services with an estimated value of over USD $1 Trillion globally3,4. For example, the complex three-dimensional structure of reefs not only provides habitat but also dissipates wave energy to protect coastlines from erosion and damage. Coastal protection and human use (including tourism, recreation and fishing) supply the greatest economic benefits from coral reefs to over half a billion people around the world. | Impacts | 3 - 3 |

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| UNESCO | Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | Coral bleaching is a stress response in which the coral animals expel their zooxanthellae, leaving the white coral skeleton visible through the transparent coral tissue7 . Bleached corals are still alive – however, even mild bleaching can result in subsequent deleterious effects, such as reduced growth and reproduction. If stressful conditions persist for several weeks, corals may die from a lack of food or from disease. Coral mortality and subsequent erosion of their skeletons reduce the structural complexity and biodiversity of the reef system. | Impacts | 3 - 3 |
| UNESCO | Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | These impacts lead to reduced habitat for marine organisms that depend upon the reef ecosystem, and fewer ecosystem goods and services, such as food, income and coastal protection, for dependent human communities. | Impacts | 3 - 3 |
| UNESCO | Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | As atmospheric carbon dioxide has raised temperatures in © The Ocean Agency, XL Catlin Seaview Survey, Lynton Burger Belize Barrier Reef Reserve System © The Ocean Agency, XL Catlin Seaview Survey, Christophe Bailhache Great Barrier Reef, Lizard Island<br>2 Impacts of Climate Change on World Heritage Coral Reefs the ocean, heat stress events causing coral bleaching have become more frequent and severe. | Impacts | 3 - 4 |
| UNESCO | Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | All three global bleaching events have caused severe bleaching and mortality of corals in various World Heritage listed reefs around the world. However, the frequency, intensity and duration of these heat stress events have worsened as global warming has increased, thereby increasing the impact on coral reefs and other marine systems around the world. | Impacts | 4 - 4 |
| UNESCO | Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | Other global factors can also exacerbate vulnerability to coral bleaching by lowering the corals' ability to recover. Approximately 30% of human-produced carbon dioxide is absorbed by the ocean's surface21 and leads to ocean acidification. Ocean acidification reduces corals' ability to build their limestone skeletons and increases bioerosion and dissolution of reefs. At high CO2 levels, ocean acidification is projected to cause reefs to erode. There is also growing evidence that intensifying storms are increasing the damage to coral reefs. Recent estimates indicate that climate-related loss of reef ecosystem services will total around US $500 billion per year or more by 21003,22. The greatest impacts are likely to be experienced by people who rely upon reef services for day-to-day subsistence. | Impacts | 4 - 4 |
| UNESCO | Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | n° Country Site 1 Australia Great Barrier Reef 2 Australia Lord Howe Island Group 3 Australia Ningaloo Coast 4 Australia Shark Bay, Western Australia 5 Belize Belize Barrier Reef Reserve System 6 Brazil Brazilian Atlantic Islands 7 Colombia Malpelo Fauna and Flora Sanctuary 8 Costa Rica Cocos Island National Park 9 Costa Rica Area de Conservación Guanacaste 10 Ecuador Galápagos Islands 11 France Lagoons of New Caledonia 12 Indonesia Komodo National Park 13 Indonesia Ujung Kulon National Park 14 Japan Ogasawara Islands 15 Kiribati Phoenix Islands Protected Area n° Country Site 16 Mexico Gulf of California 17 Mexico Archipiélago de Revillagigedo 18 Mexico Sian Ka'an 19 Palau Rock Islands Southern Lagoon 20 Panama Coiba National Park 21 Philippines Tubbataha Reefs Natural Park 22 Seychelles Aldabra Atoll 23 Solomon Islands East Rennell 24 South Africa iSimangaliso Wetland Park 25 Sudan Sanganeb Marine National Park and Dungonab Bay – Mukkawar Island Marine National Park 26 USA Everglades National Park 27 USA Papahānaumokuākea 28 Viet Nam Ha Long Bay 29 Yemen Socotra Archipelago No Stress Watch Warning Alert Level 1 Alert Level 2 NOAA Coral Reef Watch 5 km Maximum Satellite Coral Bleaching Alert Area June 2014 - April 2017<br>4 Impacts of Climate Change on World Heritage Coral Reefs 3. Observed Heat Stress and Bleaching Frequency in Reef�Containing World Heritage Properties Analysis of ocean surface temperatures recorded by satellites has been used in near real-time for over two decades to provide insight into conditions that cause coral bleaching on coral reefs24. Relevant satellite temperature records since 1985 are used here to provide over 30 years of data to assess past heat stress on World Heritage reefs. | Impacts | 5 - 6 |
| UNESCO | Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | Bleaching stress on the 29 reef-containing natural properties on the UNESCO World Heritage List was determined for historical (1985-2013) and recent (mid 2014-mid 2017) heat stress based on recently published studies10 and newly developed data25 from the United States National Ocean and Atmospheric Administration's (NOAA) Coral Reef Watch. The mid 2014-mid 2017 recent period corresponds to the third global coral bleaching event discussed in Section 2. Bleaching risk was assessed using a metric of accumulated heat stress, the Degree Heating Week (DHW). Satellite-based thresholds for bleaching-level heat stress (DHW of 4°C-weeks) and severe bleaching heat stress (8°C-weeks) are well established24; for over a decade, these thresholds have also been used to model the impact of bleaching under future climate scenarios. | Impacts | 6 - 6 |

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| UNESCO | Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | Recent heat stress (mid 2014-mid 2017, during the third global coral bleaching event) was categorized by the number and intensity of events, in a similar way as for the 1985-2013 period. The classification (color) scheme reflects both the higher impact of single severe events as well as the cumulative impact of recurrent stress, even at lower levels. Impact was considered most severe (dark red) where properties experienced three bleaching-level stress events (annual exposure to DHW ≥ 4°C-weeks, Table 1c), or two or more severe stress events (DHW ≥ 8°C-weeks, Table 1d) within the three-year period. The second-highest category of heat stress (red) included locations exposed to two bleaching-level stress events (Table 1c). A single severe stress event during the past three years was assigned to the third-highest category (orange), while locations exposed to only one bleaching-level stress event were colored yellow. Only properties that had no reefs exposed to any bleaching-level stress were assigned to the lowest category (green). | Impacts | 6 - 6 |
| UNESCO | Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | Seventy two percent of World Heritage reef properties (21 of 29) have been exposed to severe and/or repeated heat stress during the past three years. Within the three years of the current global bleaching event (mid 2014-mid 2017), 18 World Heritage reefs (62%) were in the highest impact category (dark red) at either one or both stress levels (Table 1c,d). A further three properties were exposed to NEARLY HALF OF WORLD HERITAGE PROPERTIES CONTAINING CORAL REEFS EXPERIENCED BLEACHING STRESS MORE THAN TWICE PER DECADE DURING 1985-2013; 25 OF 29 SITES EXPERIENCED BLEACHING STRESS IN THE LAST THREE YEARS. | Impacts | 6 - 6 |
| UNESCO | Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | © The Ocean Agency, XL Catlin Seaview Survey, Christophe Bailhache Komodo National Park<br>A First Global Scientific Assessment 5 recurrent bleaching stress (red) or a single severe stress event (orange). This illustrates the dramatic impact on coral reefs during this period, which has seen three consecutive years of record global temperature (2014, 2015 and 2016), and reflects an increase in bleaching frequency from that seen in the prior decades. Only four properties (14%) escaped bleaching-level heat stress during this three-year bleaching event: Brazilian Atlantic Islands (Brazil), iSimangaliso Wetland Park (South Africa), Sanganeb Marine National Park and Dungonab Bay – Mukkawar Island Marine National Park (Sudan) and Socotra Archipelago (Yemen). | Impacts | 6 - 7 |
| UNESCO | Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | HistoricalStress RecentStress Bleaching Severe 0 0 1 1 2 2 3 3 in3years Bleaching Severe 0.5 0.25 1.0 0.5 2.0 1.0 5.0 2.5<br>perdecade<br>6 Impacts of Climate Change on World Heritage Coral Reefs While the overall pattern of increased impact is reflected in both the heat stress exposure (Table 1) and observed bleaching impact (Table 2), there are some differences between the datasets, especially during lower levels of bleaching stress (4-8°C-weeks, or mild bleaching). There will always be some disagreement between remotely-sensed heat stress and measures of in situ bleaching responses. This may result from the surveyed locations not being representative of the entire property, particularly given the size of, for example, Papahānaumokuākea (USA) and the Great Barrier Reef (Australia), among the most spatially vast of all World Heritage properties. It may also reflect changing sensitivity of corals to heat stress. Furthermore, the current analysis does not consider timing of events within a period (e.g., the response of surviving corals in back-to-back heat stress events may be different between the years) or other contributing factors that can alter coral and reef resilience23. | Impacts | 7 - 8 |
| UNESCO | Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | The link between coral bleaching events and ocean heat stress exposure can also be applied to model projections of temperature to determine estimates of potential stress for the future. This allows us consideration of what the future may hold for World Heritage properties containing coral reefs. Projected stress exposure under different CO2 emissions trajectories (Representative Concentration Pathways, RCP28), as used by the Intergovernmental Panel on Climate Change (IPCC), indicate a range of projected impacts depending upon atmospheric greenhouse gas concentrations in the years to come. Future estimates of accumulated heat stress at World Heritage properties with reefs were assessed using recently published analyses29. | Impacts | 9 - 9 |
| UNESCO | Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | Current damage is already extensive and has accelerated with around 1°Cd of global-average warming19 since pre-industrial timese . Recent analyses have shown that most of the world's coral reefs will be seriously degraded at higher levels of warming22,31. It is a well-established conclusion of international peer reviewed literature and research32,33 that only meeting the most ambitious target of the United Nations Framework Convention on Climate Change (UNFCCC) Paris Agreement34, i.e., limiting the global average temperature increase to 1.5°C above pre-industrial levels, provides a chance of retaining coral-dominated communities for many reef locations around the globe. Acknowledging this and the presence of other stressors, one can look ahead to project the year in which severe bleaching stress will occur twice-per-decade (exceeding the frequency at which reefs can recover between bleaching events), and also the onset year in which severe bleaching stress will become an annual occurrence. | Impacts | 9 - 9 |

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| UNESCO | Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | The second is RCP4.5, in which emissions peak around 2040 and then decline28, although large inertia in the climate system will likely continue to raise temperature after that time but at a decelerating rate. These scenarios lead to projected global-mean temperature increases by 2100 of 4.3°C and 2.4°Cf , respectively, both of which well exceed the level of warming (1.5°C) beyond which severe degradation of the great majority of coral reefs is anticipated22. Based on recent estimates, countries' emissions are likely to raise the global-mean temperature by around 3.6°C by 2100, whereas the aggregated effects of the pledges made by countries under the Paris Agreement so far would likely result in about 3°C warming globally36,37. | Impacts | 9 - 9 |
| UNESCO | Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | Following the technique of the satellite analysis, future stress exposure is presented as the year in which stress first occurs at twice-per-decade and annual frequencies for at least 10% of reef locations within each property. This is a more conservative measure than the 10-15 years required for reefs to start to recover but has been used by the modeling community to reflect the time at which it can be certain corals no longer have sufficient time to recover between events. The color scheme for future stress exposure (Table 3) reflects that a later onset of frequent heat stress, while still damaging, is a far better outcome for coral reefs; the darkest red indicates the earliest onset of future stress. Green shading is used only where the stressful condition is not realized by 2100 in the modeling. The color categories are delineated by the same years in all analyses presented (2055, 2040 and 2025), allowing comparison between the two scenarios. Severe bleaching events 2014-17 reflect damage expected once warming results in a frequency between twice-per-decade and annual severe bleaching stress. | Impacts | 9 - 9 |
| UNESCO | Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | © The Ocean Agency, XL Catlin Seaview Survey, Christophe Bailhache Sian Ka'an<br>8 Impacts of Climate Change on World Heritage Coral Reefs TABLE 3 Onset of recurrent severe bleaching heat stress events under Representative Concentration Pathways (RCP) 8.5 and 4.5. Event frequencies are twice-per-decade and annually. | Impacts | 9 - 10 |
| UNESCO | Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | Warming of 1.5°C is recognized by many scientists to be a maximum for coral reefs to survive in the long term22,32,33, although even this will result in significant reef loss. Multiple studies support the conclusion that corals will not thrive again until atmospheric CO2 has been reduced to 320-350 ppm38,39. | Impacts | 11 - 11 |
| UNESCO | Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | 5. Summary and Solutions Climate change has been impacting coral reefs for more than three decades through the bleaching and mortality of corals due to heat stress. Bleaching events are becoming more frequent, more widespread and more severe, and are having major impacts on coral reefs globally. Warming is projected to exceed the ability of reefs to survive within 1-3 decades for the majority of World Heritage sites containing coral reefs, and the impact is aggravated by the additional pressures such as ocean acidification and local stressors. | Impacts | 11 - 11 |
| UNESCO | Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | LOCAL MANAGEMENT IS NO LONGER SUFFICIENT TO ENSURE THE FUTURE OF CORAL REEFS. PROTECTING WORLD HERITAGE REEFS REQUIRES COMPLEMENTARY NATIONAL AND GLOBAL EFFORTS TO LIMIT WARMING TO 1.5°C © The Ocean Agency, XL Catlin Seaview Survey, Christophe Bailhache Great Barrier Reef, Wilson Reef<br>10 Impacts of Climate Change on World Heritage Coral Reefs Until now, the focus for World Heritage sites in maintaining the Outstanding Universal Value of their key features has been on maintaining integrity through on-site management and pressures, and national or regional enabling legislation. Efforts to restore resilience and reduce local human stressors remain necessary but are no longer sufficient. For the first time, a ubiquitous global threat - heat stress sufficient to cause frequent severe bleaching and mortality - now threatens the OUV of World Heritage sites in a way that cannot be resolved through local management alone. The only viable solution is for all countries with World Heritage coral reefs to not only act to reduce local stressors but also to reduce their greenhouse gas emissions to net zero, along with supporting active CO2 removal from the atmosphere and upper ocean. | Impacts | 11 - 12 |

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| UNESCO | Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | 6. Additional Research This analysis provides a first scientific assessment of past impacts on World Heritage coral reefs and the risks under different emissions scenarios in coming decades. Further work to strengthen and provide a more comprehensive analysis to inform the World Heritage Committee and the global community could include efforts to: f augment historical data collation efforts and expand monitoring of reef condition for all World Heritage properties containing coral reefs; f enhance analysis of past bleaching and heat stress events to test for impacts of back-to-back heat stress or local factors that alter reef resilience; f undertake high-resolution (downscaled) future projection analysis under both RCP2.6 and the new RCP1.9 scenarios, to fully understand the implications of meeting the long�term goal of the Paris Agreement for World Heritage properties. Under RCP2.6 emissions peak during the current decade, 2010-2020, and then decline substantially, resulting in a projected peak global temperature increase of 1.6°C and returning to 1.5°C or below by 2100g . RCP1.9 is being discussed as an emissions pathway that results in a peak global warming of around 1.5°C, and returning to around 1.3°C by 2100; f increase capacity for the detection of impacts on corals, prior to visible signs of bleaching, and how impacts may be alleviated by physical and other mechanisms that confer bleaching resistance and resilience; f expand the consideration of impacts beyond corals, to include broader ecosystem impacts of warming and acidification, and their socio-economic importance; f identify and protect coral reefs (World Heritage or other) that stand in the best position to survive climate change and which are best located to help regenerate other coral communities once ocean conditions have stabilized; and f develop guidance to support the management of World Heritage reefs in the face of climate change, and for industries that depend upon reefs (to enhance social adaptive capacity). | Impacts | 12 - 12 |
| UNESCO | Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | Acknowledgements The authors thank Tim Badman (IUCN), Sandeep Sengupta (IUCN), Michiel Schaeffer and Bill Hare (Climate Analytics) for review input to this document; and Nicole Lampe of Resource Media for editing. NOAA Coral Reef Watch data products are supported by the NOAA Coral Reef Conservation Program (CRCP) and the NOAA Ocean Remote Sensing Program. The contents in this document are solely the opinions of the authors and do not constitute a statement of policy, decision or position on behalf of NOAA or the U.S. Government, the United Nations Educational, Scientific and Cultural Organization (UNESCO), the International Union for Conservation of Nature (IUCN), or of the institutions of other authors.<br>A First Global Scientific Assessment 11 ANNEX I Natural Properties of Outstanding Universal Value Inscribed on UNESCO's World Heritage List (March 2017) that Contain Coral Reefs. Locations Are Displayed By Number in Figure 1h N° COUNTRY SITE 1 Australia Great Barrier Reef 2 Australia Lord Howe Island Group 3 Australia Ningaloo Coast 4 Australia Shark Bay, Western Australia 5 Belize Belize Barrier Reef Reserve System 6 Brazil Brazilian Atlantic Islands 7 Colombia Malpelo Fauna and Flora Sanctuary 8 Costa Rica Cocos Island National Park 9 Costa Rica Area de Conservación Guanacaste 10 Ecuador Galápagos Islands 11 France Lagoons of New Caledonia 12 Indonesia Komodo National Park 13 Indonesia Ujung Kulon National Park 14 Japan Ogasawara Islands 15 Kiribati Phoenix Islands Protected Area N° COUNTRY SITE 16 Mexico Gulf of California 17 Mexico Archipiélago de Revillagigedo 18 Mexico Sian Ka'an 19 Palau Rock Islands Southern Lagoon 20 Panama Coiba National Park 21 Philippines Tubbataha Reefs Natural PArk 22 Seychelles Aldabra Atoll 23 Solomon Islands East Rennell 24 South Africa iSimangaliso Wetland Park 25 Sudan Sanganeb Marine National Park and Dungonab Bay – Mukkawar Island Marine National Park 26 USA Everglades National Park 27 USA Papahānaumokuākea 28 Viet Nam Ha Long Bay 29 Yemen Socotra Archipelago ANNEX 2 Color Categories Used in Data Presentations of Tables 1, 2 & 3 h Full descriptions of World Heritage properties used in this publication are available at : http://whc.unesco.org/en/marine-programme/ Historicalbleachingorbleachingstress(Table1a,2a) /decade Historicalseverebleachingorstress(Table1b,2b) /decade events Recentbleachingorbleachingstress(Table1c,2c) Recentseverebleachingorstress(Table1d,2d) Futureseverestressonset(Table3a,b,c,d) 0.5 1.0 2.0 5.0 0.25 0.5 1.0 2.5 0 1 2 3 never 2055 2040 2025 onset<br>12 Impacts of Climate Change on World Heritage Coral Reefs ANNEX 3 - Literature Cited 1 Spalding MD, Ravilious C, Green EP (2001) World Atlas of Coral Reefs. United Nations Environment Programme, World Conservation Monitoring Centre. University of California Press: Berkeley. 416pp | Impacts | 12 - 14 |
| UNESCO | Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | 5 Burke L, Reytar K, Spalding M, Perry A (2011) Reefs At Risk Revisited. | Impacts | 14 - 14 |
| UNESCO | Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | 7 Baker AC, Glynn PW, Riegl B (2008) Climate change and coral reef bleaching: An ecological assessment of long-term impacts, recovery trends and future outlook. Estuarine, Coastal and Shelf Science 80:435-471. | Impacts | 14 - 14 |

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| UNESCO | Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | 14 Heron SF, Eakin CM, Maynard JA, van Hooidonk R (2016) Impacts and effects of ocean warming on coral reefs. In: Laffoley D, Baxter JM (eds) Explaining ocean warming: Causes, scale, effects and consequences. Full report. Gland, Switzerland: IUCN. pp. 177- 197. | Impacts | 14 - 14 |
| UNESCO | Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | 31 Hoegh-Guldberg O, et al. (2014) The ocean. In: Field CB, et al. (eds) Climate Change 2014: Impacts, Adaptation and Vulnerability. | Impacts | 14 - 14 |
| UNESCO | Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | 33 Schleussner C-F, et al. (2016) Differential climate impacts for policy�relevant limits to global warming: the case of 1.5°C and 2°C. | Impacts | 14 - 14 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Policy Document on the Impacts of Climate Change on World Heritage Properties<br>Design by RectoVerso Conception : RectoVerso Publications du Centre du patrimoine mondial de l'UNESCO sur le changement climatique : Case Studies on Climate Change and World Heritage – juin 2007 Rapport du patrimoine mondial N° 22 : Changement climatique et patrimoine mondial – mai 2007 Patrimoine Mondial N° 42 (magazine trimestriel) – juin 2006 Venise, Italie © Monceau Photo de couverture : © UNESCO 2008 – Imprimé par UNESCO – CLT-2008/WS/6 Source : Convention du patrimoine mondial Assemblée générale des États parties à la e Document WHC-07/16.GA/10 adopté par la 16 (octobre 2007). | Impacts | 1 - 2 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Reproduction is authorized, providing that appropriate mention is made of the source, and copies are sent to the UNESCO address below: World Heritage Centre UNESCO 7, place de Fontenoy 75352 Paris 07 SP France Tel : 33 (0) 1 45 68 15 71 Fax : 33 (0) 1 45 68 55 70 E-mail : wh-info@unesco.org Website: http://whc.unesco.org CC Policy cover 13/05/08 16:54 Page 3<br>1 Preamble and purpose Synergies with other international conventions and organizations Research needs Legal questions and alternative mechanisms Mitigation of emissions by the World Heritage community Conclusions • Annex 1 • Annex 2 1 Background 2 3 4 5 6 9 9 10 12 2 Policy Document on the Impacts of Climate Change on World Heritage Properties CONTENTS 3 CC Policy Doc-eng 13/05/08 16:43 Page 1<br>2 1. Available at: http://whc.unesco.org/en/climatechange/ and published as World Heritage Paper No. 22 in English and French. | Impacts | 2 - 4 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | 2. Full details of this meeting, including the background document and list of participants is available at: http://whc.unesco.org/en/activities/471/ The issue of the impacts of climate change on World Heritage natural and cultural properties was brought to the attention of the World Heritage Committee in 2005 by a group of concerned organisations and individuals. The Committee requested (Decision 29 COM 7B.a) the World Heritage Centre, in collaboration with the Convention's Advisory Bodies, interested States Parties and the petition�ers, to convene a broad working group of experts to review the nature and scale of the risks arising from climate change and prepare a strategy and report for dealing with the issue. In taking this decision the Committee noted '… that the impacts of climate change are affecting many and are likely to affect many more World Heritage proper�ties, both natural and cultural, in the years to come'. | Impacts | 4 - 4 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | The group of experts prepared a report on "Predicting and Managing the Effects of climate change on World Heritage' (the Report), as well as a 'Strategy to Assist States Parties to the Convention to Implement Appropriate Management Responses" (the Strategy). The Committee reviewed and endorsed these two documents1 at its 30th session (Vilnius, 2006) (Decision 30 COM 7.1), and requested all States Parties to implement the strategy so as to protect the out�standing universal values, integrity and authenticity of the World Heritage properties from the adverse impacts of climate change. | Impacts | 4 - 4 |

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| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | The Committee further requested the World Heritage Centre to develop, through a consultative process, a draft policy document on the impacts of climate change on World Heritage properties to be presented at the 31st ses�sion, and discussed subsequently at the General Assembly of States Parties in 2007. The Committee desired that the draft should include considerations on: a) Synergies between conventions on this issue, b) Identification of future research needs in this area, c) Legal questions on the role of the World Heritage Convention with regard to suitable responses to climate change, d) Linkages to other UN and international bodies dealing with the issues of climate change, e) Alternative mechanisms, other than the List of World Heritage in Danger, to address concerns of international implication, such as climatic change. | Impacts | 4 - 4 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Accordingly, a Working Group meeting2, comprising sev�eral experts and representatives of convention secretariats, was convened by the World Heritage Centre at UNESCO Headquarters in Paris on 5-6 February 2007. The draft 'Policy Document on the Impacts of Climate Change on World Heritage Properties' was prepared following this meeting and reviewed by various experts, practitioners, as well as representatives of international organizations and the civil society. This draft Policy Document was discussed at the 31st session of the World Heritage Committee (Christchurch, New Zealand, 2007). The views expressed at the Committee were incorporated, and the revised Policy Document was presented to the General Assembly of States Parties at its 16th session (UNESCO, 2007). | Impacts | 4 - 4 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | 1 Background CC Policy Doc-eng 13/05/08 16:43 Page 2<br>3 Preamble and purpose According to the IPCC3, the average temperature of the earth's surface has risen by 0.74 degrees C° since the late 1800s4 and it is projected to increase by another 1.1 to 6.4 degrees C° by the year 2099. The sea level rose on average by 10 to 20 cm during the 20th century, and an additional increase of 0.18 to 0.59 cm is projected by the end of the current century5. Small Island Developing States (SIDS) are most vulnerable to such sea level rise and severity of extreme weather conditions and could, in some cases, even become uninhabitable6. With the 4th IPCC Assessment Report (Climate Change 2007) it has been widely acknowl�edged that the scientific basis for understanding the impacts of climate change and options for adaptation and mitigation have been clearly established. | Impacts | 4 - 5 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | World Heritage cultural properties are also being variously impacted by climate change. Archaeological remains and related evidence will be affected when the hydrological, chemical and biological processes of the soil change. Since historic buildings materials are more porous than modern constructions, any increases in soil moisture might result in greater salt mobilisation; consequently drying will cause salt crystallisation to damage decorated surfaces. Timber and other organic building materials may be subject to increased biological infestation in altitudes and latitudes that may not have been previously affected. Flooding may damage building materials not designed to withstand pro�longed immersion. Increases in storminess and wind gusts can lead to structural damage. Desertification, salt weath�ering and erosion is already threatening cultural heritage in desert areas. Climate change may also cause social and cul�tural impacts, with communities changing the way they live, work, worship and socialise in buildings sites and land�scapes, possibly migrating and abandoning their built her�itage. Further, climate change may also cause impacts on livelihoods, food security, and the social fabric as a whole. | Impacts | 5 - 5 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Deeply concerned about the adverse impacts which climate change is having or may have on the Outstanding Universal Value (OUV), integrity and authenticity of World Heritage properties, the World Heritage Committee launched an ini�tiative at its 29th session (Durban 2005) to investigate the issue in detail. The resulting report on 'Predicting and Managing the effects of Climate Change on World Heritage', as well as a 'Strategy to assist States Parties to Implement Appropriate Management Responses' were considered and endorsed by the Committee at its 30th ses�sion (Vilnius, 2006)10. These two documents present a detailed analysis of the threats posed to both natural and cultural World Heritage properties by climate change and discuss some of the preventive and corrective actions that 3. Intergovernmental Panel on Climate Change – 'IPCC 4th Assessment Report: Summary for Policymakers'. | Impacts | 5 - 5 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | 2 Policy Document on the Impacts of Climate Change on World Heritage Properties CC Policy Doc-eng 13/05/08 16:43 Page 3<br>4 are possible, as well as actions relating to the sharing of information and knowledge. | Impacts | 5 - 6 |

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| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Mindful of the various issues already covered in detail in the  above-mentioned report and strategy, this policy document  is principally aimed at providing the World Heritage deci�sion / policy-makers with guidance on a limited number of  key issues (synergies, research needs and legal issues). For  all other general issues dealing with the impacts of climate  change on World Heritage properties and management  responses document WHC-06/30.COM/7.1 (World  Heritage Paper No. 22) should be consulted. | Impacts | 6 - 6 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Adaptation: the adjustment in natural or human systems,  in response to actual or expected climatic stimuli or their  effects that moderate harm or exploit beneficial opportuni�ties (IPCC). | Impacts | 6 - 6 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | The World Heritage Centre and the Advisory Bodies will  cooperate with States Parties and other relevant organiza�tions during the reactive monitoring and periodic reporting  processes and in research activities, so that the impacts of,  adaptation to, and mitigation of climate change are prop�erly assessed, reported and managed. The use of the  UNFCCC Compendium on methods and tools to evaluate  impacts of, vulnerability and adaptation to, climate change  will be promoted. | Impacts | 6 - 6 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Some properties may be able to be involved in sequestra�tion and carbon offset activities as part of broader  national mitigation approaches and this will be the pri�mary level of focus. They will also integrate these actions  in risk preparedness policies and action plans, making use  of the ‘Strategy for Risk Reduction at World Heritage  Properties’12. | Impacts | 7 - 7 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | States Parties and managers of individual World Heritage  properties will include climate change messages in commu�nication, education and interpretation activities as appro�priate, to build public awareness and knowledge of climate  change, its potential impacts on World Heritage properties  and their values, and the ongoing activities or available  options for adaptation and mitigation. | Impacts | 7 - 7 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Research needs  Key challenges  There is presently a lack of data that is specifically relevant  to understanding climate change impacts on World Heritage properties, particularly cultural properties. This  situation is further compounded by a lack of adequate  capacity and financial resources for research and its appli�cation, especially in developing countries, to understand  and address climate-related issues. Such lack of knowl�edge and capacity makes it difficult to assess the loss of  key values of World Heritage properties as a consequence  of climate change. Addressing these gaps in knowledge,  information and capacity, and performing vulnerability  assessments will assist in determining priorities for man�agement action. | Impacts | 7 - 7 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Principles  Research on climate change at World Heritage properties  will be carried out through partnerships with and influence  of those who are conducting or can carry out such research  or who fund research programmes. The site-specific nature  of the climate change problems facing properties, make  them ideal as laboratories for long-term climate change  impact monitoring and testing of innovative adaptation  solutions. | Impacts | 7 - 7 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Considerable research is currently underway on the impacts  of climate change, particularly in relation to natural ecosys�tems. However, much of this research is not focused on  World Heritage properties and thus, links will be estab�lished with relevant organizations to ensure that ongoing generic research on climate change incorporates the effects  of climate change on World Heritage properties. | Impacts | 7 - 7 |

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| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Research must draw wider conclusions or develop approaches (such as management frameworks) that enable knowledge transfer to take place among properties and regions. For example, the approach taken by the EU 6th Framework 12. Document WHC-07/31.COM/7.2 13. http://unfccc.int/files/essential_background/background_publications_htmlpdf/application/pdf/nwp_en_070523.pdf CC Policy Doc-eng 13/05/08 16:43 Page 5<br>6 Programme research project on Global Climate Change Impacts on the Built Heritage and Cultural Landscapes14 in producing a Climate Change Vulnerability Atlas and in developing drying strategies for different types of historic structures for the European Region can be a model for other regions of the world. | Impacts | 7 - 8 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Specific research priorities World Heritage site managers and researchers will continue to better develop their use of both traditional and advanced technologies in order to increase baseline data, including data on climate variables for each property or network of representative properties. This will necessitate the gather�ing of climate data sets and climate projections from vari�ous models for different regions/properties. This will enable better understanding of the links between climate change and local impacts, including the relevance of particular environmental variables to different properties. | Impacts | 8 - 8 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Three different strands of research needs have been identified: 1. Research that responds to increased risk factors such as fire, drought, floods, avalanches, glacial lake outbursts, to support disaster management plans for properties. | Impacts | 8 - 8 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | 2. Socio-economic research, such as cost-benefit analysis, valuing the economic losses from climate change and contingent valuation, as well as research into the impacts of climate change on societies, particularly tra�ditional ones or in sites such as cultural landscapes where the way of life contributes to the OUV. | Impacts | 8 - 8 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | 3. Research into the nature and sources of other stress factors (e.g. pollution, sedimentation, deforestation, poaching) impacting on properties, which can greatly reduce their resilience to the impacts of climate change. | Impacts | 8 - 8 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Advocacy and implementation Research in relation to the impacts of climate change on World Heritage properties will be linked to a clear course of follow-up action, including awareness raising. In particular the following will be ensured: 1. Research results will be translated into practical tools that can assist managers in developing their adaptive management responses. Options for the creation of a clearing-house mechanism of best-practice case studies on climate change, either separately or linked to similar mechanisms, such as those under the UNFCCC, CBD, UNCCD, or CMS will be investigated. | Impacts | 8 - 8 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | 3. The World Heritage Committee will influence and inform international research programmes of the information needs of World Heritage properties. The World Heritage Centre and Advisory Bodies will work with and seek to influence organisations that fund research to invest in research relating to climate change impacts on World Heritage properties. | Impacts | 8 - 8 |

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| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Duties and obligations of States Parties under the Convention Article 4 is a central provision of the Convention: Each State Party to this Convention recognizes that the duty of ensuring the identification, protection, conserva�tion, presentation and transmission to future generations of the cultural and natural heritage referred to in Articles 1 and 2 and situated on its territory, belongs primarily to that State. It will do all it can to this end, to the utmost of its own resources and, where appropriate, with any international assistance and co-operation, in particular, financial, artistic, scientific and technical, which it may be able to obtain. (Emphasis added) 14. http://noahsark.isac.cnr.it/ CC Policy Doc-eng 13/05/08 16:43 Page 6 7 In the context of climate change, this provision will be the basis for States to ensure that they are doing all that they can to address the causes and impacts of climate change, in relation to the potential and identified effects of climate change (and other threats) on World Heritage properties situated on their territories. | Impacts | 8 - 9 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Article 6 of the World Heritage Convention Under Article 6, '…the States Parties to this Convention recognize that [such heritage] constitutes a world heritage for whose protection it is the duty of the international com�munity as a whole to co-operate'. Under Article 6 (3), States Parties undertake 'not to take any deliberate meas�ures which might damage directly or indirectly the cultural and natural heritage'. | Impacts | 9 - 9 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Part of that international cooperation in the context of climate change will include a collaborative approach to assess and address the causes and effects of climate change on World Heritage properties. | Impacts | 9 - 9 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | • Para 132.2: Description of the property: the description of the history and development of the property can be required to include the history of threats to the property; threats arising from the effects of climate change will be particularly noted. | Impacts | 9 - 9 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | • Para 132.4: State of conservation and factors affecting the property: when adverse effects resulting from climate change are evident, climate change will be included as a threat in the description of factors affecting the property, and it will be used as a baseline to monitor the state of conservation of the property in the future. | Impacts | 9 - 9 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Monitoring Reactive monitoring Given that climate change effects are relevant to a wide range of both natural and cultural properties, the World Heritage Committee will consider that the reactive monitor�ing provisions are made more specific as a basis for moni�toring of and reporting on the site-specific effects of climate change on World Heritage properties, particularly in the following paragraphs: • Para 173 (a) relating to indications of threats or signifi�cant improvement; • Para 173 (c) relating to information on any threat or damage to or loss of outstanding universal value, integrity and/or authenticity. | Impacts | 9 - 9 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | • Paras 175 and 176 relating to reactive monitoring; in the context of necessary restoration measures to maintain its OUV these will include measures to adapt to the effects of climate change, as well as measures to mitigate those effects, at least at the site level. | Impacts | 9 - 9 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | The List of World Heritage in Danger While the enumeration of 'serious and specific dangers' under Article 11 (4) of the Convention does not specifically refer to climate change (which was not in serious contem�plation in the early 1970s), the language is clearly suffi�ciently broad to include its effects. | Impacts | 9 - 9 |

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| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Currently, only Para 179 (b) makes reference to 'climatic or other environmental factors' as a potential danger, but only in respect of cultural properties. Hence, these provisions will be clarified to include specific reference to the effects of climate change, particularly focusing on possible adap�tation measures at site level, but also recognizing that the causes of climate change 'are amenable to correction by human action' by the global community of States Parties. | Impacts | 10 - 10 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Periodic reporting Under paragraph 199 of the Operational Guidelines, States Parties are requested to submit reports on legislative and administrative provisions adopted concerning the applica�tion of the Convention, including the state of conservation of their World Heritage properties. The World Heritage Committee will consider a specific obligation for States to report on the climate change related threats and impacts to OUV, and the efforts being made by way of mitigation and adaptation measures to address them. | Impacts | 10 - 10 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Management planning and management systems Sub-paragraph 5 of para 132 requires the inclusion of a management plan in the nomination submission process, and Para 118 contemplates the inclusion of risk prepared�ness as an element in World Heritage properties manage�ment plans and training strategies. The World Heritage Committee will consider strengthening the management planning and management system provisions of the Operational Guidelines concerning site level adaptation and mitigation measures. | Impacts | 10 - 10 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | The precautionary approach in World Heritage decision-making in the context of climate change Given the increasing application of the precautionary approach in international law and policy16, the World Heritage Committee will consider specifically incorporating reference to it within the Operational Guidelines. The fact that the approach has been adopted in the UNFCCC pro�vides a useful example, and its application to protection and conservation concerning World Heritage is obvious. The UNFCCC includes this under Article 3 (Principles) as follows: 'The Parties should take precautionary measures to antici�pate, prevent or minimize the causes of climate change and mitigate its adverse effects. Where there are threats of seri�ous or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such meas�ures, taking into account that policies and measures to deal with climate change should be cost-effective so as to ensure global benefits at the lowest possible cost. To achieve this, such policies and measures should take into account different socio-economic contexts, be comprehen�sive, cover all relevant sources, sinks and reservoirs of greenhouse gases and adaptation, and comprise all eco�nomic sectors. Efforts to address climate change may be carried out cooperatively by interested Parties.'17 The explicit adoption of the precautionary approach by the World Heritage Committee as a consideration in decision�making in general will encourage States Parties and the Advisory Bodies to use the emerging knowledge relating to the implementation of the precautionary approach18 to deal more actively with risk and uncertainty when making decisions concerning the effects of climate change on World Heritage properties. | Impacts | 10 - 10 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Environmental Principles – From Political Slogans to Legal Rules. Oxford; Cooney, R. and Dickson, B. Biodiversity and the Precautionary approach: Risk and Uncertainty in Conservation and Sustainable Use, Earthscan 2006. | Impacts | 10 - 10 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Conclusions The following key principles emerge from this policy document: i. In addressing the impacts of climate change on the out�standing universal value, integrity and authenticity of World Heritage properties, the World Heritage commu�nity will work in cooperation with other partners that also have responsibility, resources and expertise related to this challenge. | Impacts | 11 - 11 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | iii. World Heritage properties will be used wherever appro�priate and possible as a means to raise awareness about the impacts of climate change upon World Heritage to act as a catalyst in the international debate and obtain support for policies to mitigate climate change, and to communicate best practices in vulnerability assess�ments, adaptation strategies, mitigation opportunities, and pilot projects. | Impacts | 11 - 11 |

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| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | CC Policy Doc-eng 13/05/08 16:43 Page 9<br>Annex 1 10 Natural heritage In order to set priorities for a management response to climate change, the following research is particularly required in relation to natural World Heritage properties: 1. General: • To identify natural World Heritage properties most at risk from the impacts of climate change to enable a clearer identification of priorities for overall response actions to avoid or alleviate impacts. | Impacts | 11 - 12 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | • To identify the most suitable monitoring and evalua�tion systems to enable the most effective detection of climate change and its impacts at natural properties to project how these impacts will threaten World Heritage values over time and space. | Impacts | 12 - 12 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | 3. Research in relation to impacts on criterion (viii) 'geodiversity': • To identify the potential direct and indirect impacts of climate change on fossil, geological and geomorpho�logic values, e.g. from sea level rise and changes in extreme weather events, fire and water regimes (e.g. | Impacts | 12 - 12 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | important for caves), weathering and erosion (e.g. | Impacts | 12 - 12 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | 4. Research in relation to impacts on criteria (ix) and (x) 'biodiversity': • To identify species and ecosystems within properties which are most threatened by climate change (e.g. species with limited altitudinal range, coral reefs, and glaciers). | Impacts | 12 - 12 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | • To identify 'climate refugia' for biodiversity values inside and outside properties. Since ongoing evolu�tionary processes are a value, it is important to have some idea where ecosystems are most likely to be able to adapt to climate change without significant loss of their functions, components and structures. | Impacts | 12 - 12 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | • To identify criterion (ix) and (x) properties most at risk, as well as means to avoid or alleviate impacts. | Impacts | 12 - 12 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | 5. Research in relation to impacts on integrity (size, shape, boundaries, buffer zones, management, threats, etc.): • To identify key direct and indirect impacts of climate change on the integrity of specific properties and how this research can best be used to guide field manage�ment responses at the site level. | Impacts | 12 - 12 |

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| Organisation | Document | Quotation Content | Codes | Page |
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| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Cultural heritage The following research in the cultural heritage area is needed in order to enable priority setting for a manage�ment response to climate change: • Understanding the vulnerability of materials (indoor, out�door, buried) to climate variables (for example, particu�larly too much or little moisture effects). | Impacts | 12 - 12 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | • Development of fail-safe methods and technologies for monitoring the impact of climate change at properties. | Impacts | 12 - 12 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | • Understanding climate change impacts causing changes in society i.e. movement of peoples, displacement of communities, their practices, livelihoods, and their rela�tion with their heritage. | Impacts | 12 - 12 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Specific research priorities CC Policy Doc-eng 13/05/08 16:43 Page 10<br>11 Future research needs in the area of climate change and cultural World Heritage are clustered under the following 5 themes: • Understanding materials vulnerability • Monitoring change • Modelling and projecting climate behaviour • Managing cultural heritage • Preventing damage Research needs have been identified from public state�ments, scientists, heritage managers and decision-makers. | Impacts | 12 - 13 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | While these have a bias to the European region where two scientific research projects on climate change impacts on cultural heritage, Engineering Historic Futures (UK) and Global Climate Change Impact on Built Heritage and Cultural Landscape (EU), have taken place, the priorities are relevant also to World Heritage. | Impacts | 13 - 13 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | 1. Understanding materials vulnerability: The environment-materials interface is an area in critical need of research. Key aspects relate to the effects of too much or too little moisture and temperature changes and how change mechanisms such as salt crystallization in materials and biological changes on the surface of materi�als are amplified. Scientific research on the impact of extreme weather (including rain penetration, high summer temperatures and chloride loading) on traditional materials and practices is needed in order to provide justification for changing a way of life that may no longer be sustainable. | Impacts | 13 - 13 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Cross-field monitoring should be used to develop key indi�cators of impact in terms of scale, time and design. | Impacts | 13 - 13 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | 2. Monitoring change: It is important to recognize that a large amount of data and tools are already available in complementary fields for cul�tural heritage, for example in geo-archaeology and in microbiology. This research needs to be built upon, though clearly specific research is needed because of the general lack of research in climate change impacts and cultural her�itage. There are also currently no standards, protocols, indi�cators and databases within the field of cultural heritage and climate change. This suggests that research needs to focus in two directions: on the impact of climate change on local scales, especially in cities, where there are concentra�tions of people and cultural heritage; and in the develop�ment of new technological tools – advanced yet simple to use on site, to enable monitoring of change and to validate conservation decisions. While sensors need to be both inex�pensive and sturdy, it is important that much progress is made in technology development, with a focus on remote sensing products such as gas phase bio-sensing. This will enable the small group of scientists working in this field to provide remote support to site managers who are prioritiz�ing the managed change of cultural heritage. | Impacts | 13 - 13 |

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| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | 3. Modelling and projecting climate behaviour: Research concerning climate change and cultural heritage, even at a European level, is in a nascent stage. This has con�centrated on broad regional climate change impacts and not on the impact on individual buildings and ensembles. | Impacts | 13 - 13 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | It is necessary to assign probabilities of damage to specific properties, but this requires ensembles of climate models to be used and for research to be carried out on sub-grid climate models. This approach would have a much better spatial resolution than the current 50km grid. State-of-the�art computer simulation must be used if site managers are to understand better the potentially catastrophic effect on properties of sporadic and extreme events and to use risk management to forecast the effect of natural disasters on specific World Heritage properties. Research on disaster preparedness must therefore focus on hazard recognition and the quantification and prioritization of climate change risks. | Impacts | 13 - 13 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | 5. Preventing damage: All cultural heritage must be considered completely vulner�able to severe natural disasters and to phenomena associ�ated with climate change. While it is not possible to prevent damage all of the time, research is imperative if damage is to be avoided at least some of the time. | Impacts | 13 - 13 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | CC Policy Doc-eng 13/05/08 16:43 Page 11<br>12 1. Should a site be inscribed on the World Heritage List while knowing that its potential OUV may disappear due to climate change impacts? | Impacts | 13 - 14 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | 2. Should a site be inscribed on the List of World Heritage in Danger or deleted from the World Heritage List due to impacts beyond control of the concerned State Party [in circumstances where these impacts have resulted in serious deterioration of or loss of OUV]? | Impacts | 14 - 14 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Inclusion on the List of World Heritage in Danger under Article 11(2) is dependent on the threats to OUV. Where the threat comes from is irrelevant. In these circumstances, a site can be inscribed on the In-Danger List even where the impacts are beyond the control of the State Party con�cerned. The World Heritage Committee has requested19 that specific criteria be developed for the inclusion of those properties which are most threatened by climate change on the List of World Heritage in Danger. Similar considera�tions apply in relation to potential delisting. | Impacts | 14 - 14 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Le projet de Document d'orientation relatif aux impacts du changement climatique sur les biens du patrimoine mon�dial a été préparé à l'issue de cette réunion et analysé par divers experts, des praticiens, ainsi que des représentants d'organisations internationales et de la société civile. | Impacts | 19 - 19 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Les inondations peuvent endommager les matériaux de construction qui ne sont pas conçus pour supporter une immersion prolongée. La fréquence accrue des tempêtes et des tornades peut causer des dommages structurels. La désertification et l'érosion causée par le sel menacent déjà le patrimoine culturel des zones désertiques. L'évolution du climat peut aussi avoir des impacts sociaux et culturels, avec des communautés qui transforment leur mode de vie, leur façon de travailler, de se recueillir et de se rencontrer dans les bâtiments, les sites et les paysages, et qui éventuel�lement émigrent et abandonnent leur patrimoine bâti. En outre, l'évolution du climat peut également avoir des réper�cussions sur les outils de travail, la sécurité alimentaire et l'ensemble du tissu social. | Impacts | 20 - 20 |

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| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Le Centre du patrimoine mondial et les Organisations consultatives coopéreront avec les États parties et les autres organisations compétentes aux processus de suivi réactif et de présentation de rapports périodiques, et aux travaux de recherche de façon à bien évaluer, décrire et gérer les impacts, l'adaptation et l'atténuation du changement climatique sur les biens du patrimoine mondial. L'usage du Recueil de la CCNUCC sur les méthodes et les outils permet�tant d'évaluer les incidences du changement climatique et la vulnérabilité et l'adaptation à ce changement, sera préconisé. | Impacts | 22 - 22 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Les États parties pourraient profiter du « Programme de travail de Nairobi sur les impacts, la vulnérabilité et l'adap�tation au changement climatique »13 dans le cadre de la CCNUCC et d'autres processus en place pour aborder la question de l'adaptation des biens du patrimoine mondial au changement climatique. Ils sont encouragés à participer aux conférences des Nations Unies sur l'évolution du climat en vue de parvenir à un accord global post-Kyoto. | Impacts | 22 - 22 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Une somme d'études considérable est en cours sur les impacts du changement climatique, pour ce qui est notam�ment des écosystèmes naturels. Toutefois, une grande part de la recherche n'est pas axée sur les biens du patrimoine mondial et des liens seront ainsi établis avec les organismes compétents pour s'assurer que la recherche générique sur le changement climatique inclue les effets de l'évolution du climat sur les biens du patrimoine mondial. | Impacts | 23 - 23 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | La recherche doit tirer de plus amples conclusions ou concevoir des stratégies (à l'exemple des cadres de gestion) qui permettent d'opérer un transfert de connaissances entre biens et régions. À titre d'exemple, l'option prise par le projet de recherche du 6e Programme-cadre de l'UE sur les impacts du changement climatique global sur le patri�moine bâti et les paysages culturels14 en dressant un atlas de la vulnérabilité au changement climatique et en mettant au point des procédés d'assèchement pour différents types de structures historiques de la région européenne, peut servir de modèle à d'autres régions du monde. | Impacts | 23 - 23 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Priorités de recherche spécifiques Les chercheurs et les gestionnaires de sites du patrimoine mondial continueront à parfaire leur usage des méthodes classiques et des technologies de pointe pour enrichir les données de référence, y compris celles qui concernent les variables climatiques correspondant à chaque bien ou à un réseau de biens représentatifs. Cela nécessitera de recueillir des sommes de données et des projections sur le climat provenant de différents modèles et pour différents biens/régions. Cela permettra plus aisément de compren�dre les liens entre le changement climatique et les impacts locaux, ainsi que la pertinence des variables environnemen�tales particulières à chaque site. | Impacts | 23 - 23 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | 2. La recherche socio-économique, telle que l'analyse coûts-avantages, qui mesure les pertes économiques dues au changement climatique et les estimations qui en dépendent, ainsi que l'étude des impacts du change�ment climatique sur les sociétés, en particulier les socié- tés traditionnelles, ou sur les sites tels que les paysages culturels où le mode de vie contribue à la valeur univer�selle exceptionnelle. | Impacts | 23 - 23 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Promotion et mise en œuvre L'étude des impacts du changement climatique sur les biens du patrimoine mondial sera liée à une action de suivi, mais aussi de sensibilisation, dont le cours sera clairement établi. Elle veillera, en particulier, à ce que : 1. Les résultats de la recherche se traduisent en outils pra�tiques pouvant aider les gestionnaires à mettre au point 14. http ://noahsark.isac.cnr.it/ CC Policy Doc-fr 13/05/08 16:45 Page 6<br>7 leurs mesures de gestion adaptative. Des recherches seront faites sur les options relatives à la création d'un mécanisme centralisateur d'études de cas des meilleures pratiques sur l'évolution du climat, soit indépendant, soit lié à des mécanismes analogues, comme ceux de la CCNUCC, de la CDB, de la CCD ou de la CMS. | Impacts | 23 - 24 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Dans le contexte de l'évolution du climat, cette disposition servira de fondement aux États pour s'assurer qu'ils font tout leur possible pour traiter les causes et les effets du changement climatique par rapport aux impacts potentiels et réels de ce changement (et d'autres menaces) sur les biens du patrimoine mondial situés sur leur territoire. | Impacts | 24 - 24 |

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| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Suivi  Section IV.A : Suivi réactif  Étant donné que les effets du changement climatique tou�chent un large éventail de biens culturels et naturels, le Comité du patrimoine mondial veillera à ce que les disposi�tions de suivi réactif revêtent un caractère plus spécifique  en tant que base pour le suivi et la diffusion d'informations  sur les impacts du changement climatique propres à cha�que bien du patrimoine mondial, en particulier dans les paragraphes suivants :  • Para 173 (a) concernant l'indication des menaces ou  d'une amélioration sensible ;   • Para 173 (c) concernant les informations sur toute  menace ou dommage ou perte de la valeur universelle  exceptionnelle, de l'intégrité et/ou de l'authenticité ;  • Para 175 et 176 à propos du suivi réactif : dans le cadre  des mesures de restauration nécessaires au maintien de  la VUE s'ajouteront des mesures d'adaptation aux effets  du changement climatique, ainsi que des mesures d'atté-  nuation de ces effets, tout du moins au niveau du site. | Impacts | 25 - 25 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Présentation de rapports périodiques   Conformément au paragraphe 199 des Orientations, les  États parties sont invités à présenter des rapports sur les  dispositions législatives et les règlements administratifs  qu'ils auront adoptés pour l'application de la Convention,  incluant l'état de conservation des biens du patrimoine  mondial situés sur leur territoire. Le Comité du patrimoine  mondial envisagera l'obligation spécifique pour les États  parties de signaler les dangers et les impacts pour la VUE  liés à l'évolution du climat, et les efforts accomplis à travers  des mesures d'adaptation et d'atténuation pour y faire  face. | Impacts | 25 - 25 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Environmental Principles – From Political Slogans to Legal Rules. Oxford; Cooney, R. et Dickson, B. Biodiversity and the Precautionary approach : Risk and Uncertainty in Conservation and Sustainable Use, Earthscan 2006. | Impacts | 26 - 26 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Conclusions  Les principes directeurs qui se dégagent de ce document  d'orientation sont les suivants :   i. En traitant les impacts du changement climatique sur la  valeur universelle exceptionnelle, l'intégrité et l'authen�ticité des biens du patrimoine mondial, la communauté  du patrimoine mondial travaillera en coopération avec  d'autres partenaires qui auront aussi la responsabilité,  les moyens et les compétences nécessaires pour relever  ce défi. | Impacts | 27 - 27 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | iii. Les biens du patrimoine mondial seront utilisés, le cas  échéant et si possible, comme un moyen de sensibiliser  l'opinion aux impacts du changement climatique sur le  patrimoine mondial servant de catalyseur au débat inter�national, et d'obtenir un appui en faveur de politiques d'atténuation du changement climatique, mais aussi de  diffuser les meilleures pratiques concernant les évalua�tions de vulnérabilité, les stratégies d'adaptation, les  possibilités d'atténuation et les projets pilotes. | Impacts | 27 - 27 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | • Identifier les systèmes d'évaluation et de suivi les mieux  adaptés pour permettre une meilleure détection du  changement climatique et de ses impacts sur les biens  naturels afin de projeter la façon dont ces impacts  mettront en péril les valeurs du patrimoine mondial  dans le temps et l'espace. | Impacts | 28 - 28 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | 3. Recherches relatives aux impacts sur le critère (viii) de  « géodiversité » :  • Identifier les effets potentiels directs et indirects du  changement climatique sur les valeurs géomorpholo�giques, géologiques et fossiles, qu'il s'agisse de l'élé-  vation du niveau de la mer et des modifications des phénomènes climatiques extrêmes, des incendies et  des régimes hydrologiques (important pour les grot�tes), de la dégradation et de l'érosion (important pour  les fossiles). | Impacts | 28 - 28 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | 4. Recherches relatives aux impacts sur les critères (ix) et  (x) de « biodiversité » :  • Identifier à l'intérieur des biens les espèces et les écosystè- mes les plus exposés aux risques de changement climati�que (espèces dont l'aire de répartition est limitée en  altitude, récifs coralliens et glaciers). | Impacts | 28 - 28 |

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| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | • Identifier les biens les plus menacés au regard des critères (ix) et (x), ainsi que les moyens d'éviter ou d'atténuer les impacts. | Impacts | 28 - 28 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | 5. Recherches relatives aux impacts sur l'intégrité (dimen�sion, forme, limites, zones tampons, gestion, mise en péril, etc.) : • Identifier les principaux impacts directs et indirects du changement climatique sur l'intégrité de bien spécifi�ques et la manière dont ces recherches peuvent être utilisées au mieux pour guider les décisions locales prises en matière de gestion au niveau du site. | Impacts | 28 - 28 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Les futurs besoins de la recherche dans le domaine du changement climatique et du patrimoine culturel mon�dial se résument en cinq thèmes : • Compréhension de la vulnérabilité des matériaux • Évolution du suivi • Modélisation et projection de l'action du climat • Gestion du patrimoine culturel • Prévention des dommages Les besoins de la recherche ont été identifiés à partir de déclarations publiques, de scientifiques, de gestionnaires du patrimoine et de décideurs. Malgré l'importance que leur accorde la région européenne où ont été lancés deux projets de recherche scientifique sur les impacts du change�ment climatique sur le patrimoine culturel – Engineering Historic Futures (Royaume-Uni) et Global Climate Change Impact on Built Heritage and Cultural Landscape (UE) – les priorités vont également au patrimoine mondial. | Impacts | 29 - 29 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | 3. Modélisation et projection de l'action climatique : Les recherches concernant le changement climatique et le patrimoine culturel, même au niveau européen, en sont à leurs balbutiements. Elles se concentrent sur les larges impacts du changement climatique régionaux et non sur l'impact produit sur les ensembles et les bâtiments indivi�duels. Il est nécessaire de classer les probabilités de dom�mages causés à des biens spécifiques, mais pour cela il faut utiliser des ensembles de modèles climatiques et faire des CC Policy Doc-fr 13/05/08 16:45 Page 12 13 recherches sur des modèles de climat en réseau secondaire. | Impacts | 29 - 30 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | 2. Un site devrait-il être inscrit sur la Liste du patrimoine mondial en péril ou être rayé de la Liste du patri�moine mondial en raison des impacts qui échappent au contrôle de l'État partie concerné [au cas où ces impacts ont entraîné une grave détérioration ou une perte de la VUE] ? | Impacts | 31 - 31 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | L'inclusion sur la Liste du patrimoine mondial en péril d'après l'article 11(2) dépend des menaces pesant sur la VUE. La provenance du danger est hors de question. Dans ce cas, un site peut être inscrit sur la Liste en péril même si les impacts échappent au contrôle de l'État partie concerné. Le Comité du patrimoine mondial a demandé que des critères spécifiques soient établis pour inscrire sur la Liste du patrimoine mondial en péril les biens qui sont les plus menacés par le changement climatique. Ce même raisonnement vaut pour le retrait potentiel de la Liste. | Impacts | 31 - 31 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | WH_and_Tourism_23_may.indd 3 24/05/2016 06:34 WH_and_Tourism_23_may.indd 4 H_and_Tourism_23_may.indd 4 24/05/2016 05:25 4/05/2016 05:25 Foreword 5– F rom Venice and its Lagoon to the Galápagos Islands, some of the world's most iconic World Heritage sites are vulnerable to climate change. In this new analysis, the United Nations Environment Programme (UNEP), the United Nations Educational, Scientific and Cultural Organization (UNESCO), and the Union of Concerned Scientists (UCS) highlight the growing climate risks to World Heritage sites and recommend a clear and achievable response. Globally, we need to understand more about how climate change will affect all World Heritage sites, and how it will interact with and amplify the effects of other stresses, including urbanization, pollution, natural resource extraction and, increasingly, tourism. | Impacts | 5 - 7 |

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| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | There are more than 1 000 World Heritage properties in 163 countries and a great many of them are important tourist destinations. At its best, tourism drives economic development and brings needed financial and social benefits, but, as this report demonstrates, rapid or unplanned tourism developments, or excessive visitor numbers, can also have a negative effect on the properties. Climate change is likely to exacerbate existing stresses and bring direct impacts of its own. Sea-level rise, higher temperatures, habitat shifts and more frequent extreme weather events such as storms, floods and droughts, all have the potential to rapidly and permanently change or degrade the very attributes that make World Heritage sites such popular tourist destinations. | Impacts | 7 - 7 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | As this report shows, World Heritage properties provide opportunities for both climate mitigation and adaptation. For example, well-preserved forests and coastal habitats can help store carbon and provide vital ecosystem services, including natural protection against storms and floods. World Heritage sites can also act as learning laboratories for the study and mitigation of climate impacts, as well as being places to test resilient management strategies. | Impacts | 7 - 7 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | WH_and_Tourism_24_may.indd 6 25/05/2016 05:41 Contents 7– Foreword 5 Acknowledgements 6 About this report 8 Executive summary 9 WORLD HERITAGE AND TOURISM IN A CHANGING CLIMATE 11 RECOMMENDATIONS 27 CASE STUDIES 33 AFRICA Bwindi Impenetrable National Park, Uganda 34 Ruins of Kilwa Kisiwani and Ruins of Songo Mnara, United Republic of Tanzania 36 Cape Floral Region Protected Areas, South Africa 38 Lake Malawi National Park, Malawi 40 ARAB WORLD Ouadi Qadisha (the Holy Valley) and the Forest of the Cedars of God (Horsh Arz el-Rab), Lebanon 42 Wadi Rum Protected Area, Jordan 44 Ancient Ksour of Ouadane, Chinguetti, Tichitt and Oualata, Mauritania 45 ASIA AND THE PACIFIC Rock Islands Southern Lagoon, Palau 46 Hoi An Ancient Town, Viet Nam 47 Shiretoko, Japan 47 Komodo National Park, Indonesia 48 Sagarmatha National Park, Nepal 48 Lagoons of New Caledonia: Reef Diversity and Associated Ecosystems (France) 49 Rice Terraces of the Philippine Cordilleras, Philippines 50 Golden Mountains of Altai, Russian Federation 50 East Rennell, Solomon Islands 50 NORTH AMERICA Yellowstone National Park, United States of America 52 Statue of Liberty, United States of America 56 Old Town Lunenburg, Canada 58 Mesa Verde National Park, United States of America 59 LATIN AMERICA Port, Fortresses and Group of Monuments, Cartagena, Colombia 60 Coro and its Port, Venezuela 63 Galápagos Islands, Ecuador 64 Huascarán National Park, Peru 68 Atlantic Forest South-East Reserves, Brazil 70 Rapa Nui National Park (Easter Island), Chile 71 EUROPE Ilulissat Icefjord (Greenland), Denmark 72 Heart of Neolithic Orkney, United Kingdom of Great Britain and Northern Ireland; Stonehenge, Avebury and Associated Sites, United Kingdom of Great Britain and Northern Ireland 76 Wadden Sea, Netherlands, Germany and Denmark 80 Venice and its Lagoon, Italy 84 References 88 Contents WH_and_Tourism_24_may.indd 7 25/05/2016 05:41 8 World Heritage and Tourism in a Changing Climate ABOUT THIS REPORT This report provides an overview of the increasing vulnerability of World Heritage sites to climate change impacts and the potential implications for and of global tourism. It also examines the close relationship between World Heritage and tourism, and how climate change is likely to exacerbate problems caused by unplanned tourism development and uncontrolled or poorly managed visitor access, as well as other threats and stresses. | Impacts | 8 - 10 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Most importantly, they provide examples of a wide range of climate impacts, supported by robust scientific evidence. | Impacts | 10 - 10 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | WH_and_Tourism_23_may.indd 8 H_and_Tourism_23_may.indd 8 24/05/2016 05:25 4/05/2016 05:25 Executive summary 9– Climate change is fast becoming one of the most significant risks for World Heritage sites worldwide. Unequivocal scientific evidence shows that concentrations of the main greenhouse gas, carbon dioxide, in the atmosphere are greater now than at any time in the past 800 000 years and that global temperatures have increased by 1ºC since 1880. | Impacts | 10 - 11 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | At many World Heritage sites, the direct and indirect impacts of climate change may present a threat to their outstanding universal value (OUV), integrity and authenticity. Climate change is a threat multiplier, and will increase vulnerability and exacerbate other stresses including, but not limited to, pollution, conflict over resources, urbanization, habitat fragmentation, loss of intangible cultural heritage and the impacts of unplanned or poorly managed tourism. | Impacts | 11 - 11 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | The tourism sector itself is vulnerable to climate change. Threats include more extreme weather events, increasing insurance costs and safety concerns, water shortages, and loss and damage to assets and attractions at destinations. | Impacts | 12 - 12 |

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| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | This report and its case studies demonstrate the urgent need to better understand, monitor and address climate change threats to World Heritage sites. Policy guidance that could steer efforts already exists – including the binding Policy Document on the Impacts of Climate Change on World Heritage Properties (http://whc.unesco. | Impacts | 12 - 12 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | org/uploads/activities/documents/activity-397- 2.pdf) adopted by the General Assembly of States Parties to the World Heritage Convention at its 16th session in 2007; sustainable tourism policy orientations that define the relationship between World Heritage and sustainable tourism, adopted by the World Heritage Committee at its 34th session in 2010 (http://whc.unesco.org/en/decisions/4240/); the ICOMOS International Cultural Tourism Charter Principles; and the 2006 Strategy to Assist States Parties to the Convention to Implement Appropriate Management Responses. Additional measures also need to be taken to increase the resilience of cultural and natural heritage, reduce the impacts of both climate change and unsustainable tourism and increase financing and resources for managing protected areas. | Impacts | 12 - 12 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | 10 World Heritage and Tourism in a Changing Climate The Prehistoric Sites and Decorated Caves of the Vézère Valley in France, with their famous prehistoric paintings, have been closed to tourists since 1963 owing to the deleterious effects of large numbers of visitors entering the caves. | Impacts | 12 - 12 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | WH_and_Tourism_23_may.indd 10 H_and_Tourism_23_may.indd 10 24/05/2016 05:25 4/05/2016 05:25 World Heritage and tourism in a changing climate 11– Climate change is one of the most significant risks for World Heritage to emerge since the adoption of the World Heritage Convention in 1972 (Box 1). Unequivocal scientific evidence shows that the concentration of the main greenhouse gas, carbon dioxide (CO2 ), in the atmosphere is greater now than at any time in the past 800 000 years and that most of the increase has occurred since 1970 (IPCC 2014). Carbon dioxide emissions from fossil fuel combustion and industrial processes accounted for about 78 per cent of greenhouse gas emissions from 1970 to 2010. The tourism sector is responsible for about 5 per cent of global CO2 emissions (Fischedick et al. 2014; UNWTO 2008), and the sector's emissions are projected to grow rapidly with increasing global travel. | Impacts | 12 - 13 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | To give just one example of the scale of the problem, coral reefs – which are represented in many tropical marine World Heritage sites – are particularly vulnerable to climate change and other environmental stresses. More than half of the world's reefs are at risk of degradation (Gattuso et al. 2014; Burke et al. 2011). According to the World Resources Institute, more than 275 million people worldwide live in the direct vicinity World Heritage and tourism in a changing climate Venice and its Lagoon, Italy WH_and_Tourism_23_may.indd 11 H_and_Tourism_23_may.indd 11 24/05/2016 05:25 4/05/2016 05:25 of reefs, at least 93 countries and territories benefit from tourism associated with coral reefs, and in 23 of these, reef tourism accounts for 15 per cent or more of gross domestic product (GDP) (Burke et al. 2011). Reefs worldwide are being directly affected by warming waters and ocean acidification, and climate change is also exacerbating other localized stresses (Gattuso et al. 2014; Hoegh-Guldberg et al. 2007). Even under the most ambitious current reduction scenarios for global greenhouse gas emissions, 70 per cent of corals worldwide are projected to suffer from long-term degradation by 2030 (Frieler et al. | Impacts | 13 - 14 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | 2012), putting the reefs protected in many World Heritage sites at significant risk. | Impacts | 14 - 14 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Climate change is both a direct threat and a threat multiplier. Worsening climate impacts are cumulative, and often exacerbate the vulnerability of World Heritage sites to many other existing risks, including uncontrolled tourism, lack of resources for effective management, war, terrorism, poverty, urbanization, infrastructure, oil and gas 12 World Heritage and Tourism in a Changing Climate Box 1 The World Heritage Convention and criteria for selection Adopted in 1972, the World Heritage Convention protects natural diversity and cultural wealth of global significance, the importance of which transcends national boundaries (UNESCO). The roots of the convention lie in efforts during the late 1950s and 1960s to encourage international cooperation to protect cultural heritage and extraordinary natural areas for the benefit of future generations, and for all humankind. | Impacts | 14 - 14 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Higher temperatures are driving extraordinary environmental changes: the melting of polar ice sheets and glaciers; thawing of Arctic tundra; increases in extreme weather events, including more severe storms, floods and droughts; accelerating sea-level rise and coastal erosion; desertification; more and larger wildfires; and changes in species distribution and ecosystems. | Impacts | 15 - 15 |

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| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Although there is potential for some species to move and shift their ranges in response to climate change in natural World Heritage sites, and many ecosystems exhibit some degree of climate resilience, adaptive capacity is reduced by other stresses including habitat loss, degradation and fragmentation. The speed of climate change and lack of habitat connectivity will severely limit ecosystem response in many cases, and will require the adoption of new and innovative management practices (Welling et al. 2015; Stein et al. 2014; Markham 1996). | Impacts | 15 - 15 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Protecting large intact ecosystems is the most effective way of maintaining the adaptive capacity of natural World Heritage sites. For existing sites this means an increased emphasis on expanding and managing buffer zones and on ensuring connectivity between sites and other protected areas (Kormos et al. 2015). The need to adapt boundaries may be a significant issue for World Heritage sites in a changing climate, and in many technology, monumental arts, town�planning or landscape design; (iii) To bear a unique or at least exceptional testimony to a cultural tradition or to a civilization which is living or which has disappeared; (iv) To be an outstanding example of a type of building, architectural or technological ensemble or landscape which illustrates (a) significant stage(s) in human history; (v) To be an outstanding example of a traditional human settlement, land-use, or sea-use which is representative of a culture (or cultures), or human interaction with the environment especially when it has become vulnerable under the impact of irreversible change; (vi) To be directly or tangibly associated with events or living traditions, with ideas, or with beliefs, with artistic and literary works of outstanding universal significance (the Committee considers that this criterion should preferably be used in conjunction with other criteria); (vii) To contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance; (viii) To be outstanding examples representing major stages of Earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features; (ix) To be outstanding examples representing significant on-going ecological and biological processes in the evolution and development of terrestrial, freshwater, coastal and marine ecosystems and communities of plants and animals; (x) To contain the most important and significant natural habitats for in-situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation. | Impacts | 15 - 15 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Historic buildings and monuments at World Heritage sites are vulnerable to climate-related damage from extreme wind and rainfall events, as well as from coastal erosion, flooding and increasing damp and other impacts. Building foundations can be destabilized by increases or decreases in soil moisture, changes in the freeze/thaw cycle or, at Arctic sites, by thawing permafrost. Climate fluctuations inside buildings – the effect of higher temperatures and humidity – can cause mould, rot and insect infestations (Sabbioni et al. 2008). Changes in temperature and water interactions are particularly important for earthen architecture, and many such sites – for example the Djenné mosque in Mali – are at risk from climate change (Brimblecombe et al. | Impacts | 16 - 16 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | 2011). Rising sea levels in the Adriatic have already damaged hundreds of buildings in Venice. | Impacts | 16 - 16 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Climate change and the World Heritage Convention It has now been more than a decade since the issue of climate change impacts on natural and cultural heritage properties was formally brought to the attention of the World Heritage Committee (Welling et al. 2015). At its 29th session in Durban, South Africa in 2005, the World Heritage Committee called on States Parties to identify the properties most at risk from climate change and encouraged UNESCO "to ensure that the results about climate change affecting World Heritage properties reach the public at large, in order to mobilize political support for activities against climate change and to safeguard in this way the livelihood of the poorest people of our planet (Decision 29 COM 7B.a). This resulted in a ground-breaking report, Predicting and Managing the Effects of Climate Change on World Heritage (UNESCO 2007b), as well as the Strategy to Assist States Parties to the Convention to Implement Appropriate Management Responses (UNESCO 2007c). At its 30th session (Vilnius, 2006), the World Heritage Committee requested all States Parties to implement the strategy so as to protect the OUV, integrity and authenticity of World Heritage properties from the adverse impacts of climate change. In 2007, at its 16th session, the General Assembly of States Parties adopted a binding Policy Document on the Impacts of Climate Change on World Heritage Properties (UNESCO 2007a). Progress on implementing the strategy and the policy in most countries, however, has been quite limited to date. Furthermore, there has not yet been a comprehensive, science-based assessment of climate impacts and vulnerability at all World Heritage sites. Nonetheless, an increasing amount of data about climate change in relation to World Heritage sites has become available during the last decade or so. | Impacts | 16 - 16 |

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| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | A 2005 survey by the UNESCO World Heritage Centre found that for 72 per cent of properties for which responses were received from States Parties, climate change was acknowledged as a threat to natural and cultural heritage (UNESCO 2007b). In 2007, UNESCO identified a number of World Heritage sites at risk from climate change, including major tourist destinations such as Venice, Italy; Kilimanjaro National Park, Tanzania; Sagarmatha National Park, Nepal; and the historic centres of Český Krumlov and Prague in the Czech Republic (UNESCO 2007d). | Impacts | 16 - 16 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | In 2014, a global analysis by researchers at the University of Innsbruck and the Potsdam Institute for Climate Impact Research identified more than 130 cultural World Heritage sites at long-term risk from sea-level rise, including India's Elephanta Caves, Mont-Saint-Michel and its Bay in France and the Archaeological Site of Carthage in Tunisia (Marzeion and Levermann 2014). | Impacts | 16 - 16 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | 14 World Heritage and Tourism in a Changing Climate WH_and_Tourism_23_may.indd 14 H_and_Tourism_23_may.indd 14 24/05/2016 05:25 4/05/2016 05:25<br>Also in 2014, the International Union for the Conservation of Nature's IUCN World Heritage Outlook declared climate change to be the most serious potential threat to natural World Heritage sites worldwide (Osipova et al. 2014a). Looking more widely at all types of threat, the report also noted that only half of all natural or mixed sites were routinely monitored; more than a third had serious concerns about the levels of conservation; and 13 per cent of sites had ineffective levels of protection and management. Monitoring threats and impacts of all types, including climate change, is critical for ensuring that sites retain their OUV status. In many countries, IUCN found that existing monitoring programmes and management were weak or insufficient (Osipova et al. 2014a). | Impacts | 16 - 17 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Official reporting on threats to specific sites under the World Heritage Convention is through state of conservation (SOC) reports produced by the UNESCO World Heritage Centre and the advisory bodies – the International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM), the International Council on Monuments and Sites (ICOMOS) and IUCN. The publicly accessible online World Heritage State of Conservation Information System contains many reports that identify climate-related threats (http://whc.unesco.org/en/soc). During the period 1979–2013, more than 2 600 SOC reports were submitted, with 70 per cent of natural and mixed sites and 41 per cent of cultural sites being assessed at least once. Some 77 per cent of all reports identified management and institutional factors as threats, including a lack of management plans or problems with implementing them; boundary issues; problems with legal frameworks and governance; and scarcity of financial or human resources. The second most reported category of threat was from buildings and development including housing, commercial and industrial India's Elephanta Caves are one of 130 cultural World Heritage sites identified in a recent academic study as being at long-term risk from sea-level rise. | Impacts | 17 - 17 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | The UNESCO analysis shows that notification of climate change threats is increasing in SOC reports but, compared to what we know is actually happening on the ground, the issue is clearly still very significantly under-represented in reporting and threat assessment for World Heritage sites as a whole. Taking just the 30 case studies and sketches highlighted in this report, several have never had SOC reports prepared since their inscription, and for those that have, climate change has not always been identified as a threat, even when there is increasing evidence that this is the case. Despite the growing recognition of climate impacts in SOC reports, there remains a lack of comprehensive and detailed system�wide information and analysis available on the projected impacts of climate change on World Heritage sites and their vulnerability. | Impacts | 18 - 18 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | The IUCN World Heritage Outlook is repeated every three years for natural sites, but no such periodic assessment process yet exists for cultural sites. Both ICOMOS, through its Heritage at Risk reporting system (http://www.icomos.org/en/get�involved/inform-us/heritage-alert/heritage-at-risk�reports) and the World Monuments Fund, through its World Monuments Watch programme, address risks to cultural heritage, but neither has yet comprehensively included climate change matters within its scope, even though both have included specific case studies that address the risks posed by climate change. Several countries, including, for example, Canada, the United Kingdom (UK) and the United States of America (USA), have carried out or are in the process of completing comprehensive climate vulnerability assessments for individual World Heritage properties or for large portions of their protected area systems. | Impacts | 18 - 18 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | The Paris Agreement and Agenda 2030 With evidence of severe and accelerating climate impacts on World Heritage properties growing across the globe, and the need to reduce the risk to their OUV and associated tourist economies becoming more urgent, two recent international 16 World Heritage and Tourism in a Changing Climate Traditional earthen buildings such as the Djenné mosque in Mali are particularly susceptible to changes in temperature and humidity. | Impacts | 18 - 18 |

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| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Three ground-breaking aspects of the Paris Agreement will be vital for the future management and preservation of World Heritage sites. First, the new emphasis on preventing deforestation will increase the importance of forest conservation efforts in World Heritage sites, their buffer zones and surrounding areas. Eighteen Latin American governments at COP21 pledged to use their protected area systems as tools for climate mitigation and adaptation. Key measures include carbon sequestration and preserving ecosystem services to reduce disaster risk, thus highlighting the positive role that natural World Heritage sites can play in national climate strategies. A recent IUCN study found that an estimated 5.7 billion tonnes of forest biomass carbon is stored within natural World Heritage sites in the pan-tropical regions of the world alone (Osipova et al. | Impacts | 19 - 19 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Secondly, the Paris Agreement highlighted the need to implement a new international approach to managing climate-driven disasters by shifting from a focus on reducing disaster losses to a comprehensive management vision – building on the Sendai Framework for Disaster Risk Reduction 2015–2030 (UNISDR 2015) – that includes risk assessment, adaptation planning and resilience building. | Impacts | 19 - 19 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Goal 13 calls for taking “urgent action to combat climate change and its impacts”. Goal 14’s targets focus on sustainable use and conservation of the oceans, including minimizing and addressing the impacts of ocean acidification; conserving at World Heritage and tourism in a changing climate 17– WH_and_Tourism_23_may.indd 17 H_and_Tourism_23_may.indd 17 24/05/2016 05:25 4/05/2016 05:25 18 World Heritage and Tourism in a Changing Climate least 10 per cent of coastal and marine areas; and increasing the economic benefits to small island developing states through the sustainable use of marine resources, including through tourism. | Impacts | 19 - 20 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Responsible tourism can be a driver of sustainable development and the preservation of natural and cultural heritage, but if unplanned and poorly managed it can be socially, economically and culturally disruptive and cause damage and degradation to sensitive ecosystems, landscapes, monuments and communities (WHC 2012). The 2011 ICOMOS Paris Declaration on Heritage as a Driver of Development (ICOMOS 2011) stated clearly that “local participation, drawing on local perspectives, priorities and knowledge, is a pre�condition of sustainable tourism development”. | Impacts | 20 - 20 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Tourism itself is highly vulnerable to climate change. Threats include changing weather systems and travel seasons at destinations, more extreme weather events, increasing insurance costs, water shortages and growing tourist exposure to some vector-borne diseases. Damage to cultural heritage, species loss and natural habitat degradation will also negatively affect tourism. | Impacts | 20 - 20 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Coastal tourism is the largest component of the sector globally, and will be heavily affected by rising sea levels, coastal flooding, beach erosion and worsening storm surges. For example, a 1-metre sea-level rise would be likely to inundate up to 60 per cent of the Caribbean region’s tourist resort properties (Nichols 2014). Coral reefs contribute US$ 11.5 billion to the global tourism economy (Wong et al. 2014) and climate change is a major threat to these ecosystems. | Impacts | 20 - 20 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Climate impacts at World Heritage sites will affect a broad range of tourism segments including beach and coastal vacations; the cruise industry; ecotourism; dive and safari tourism; nature and outdoor tourism including bird watching, hiking, trekking, climbing WH_and_Tourism_23_may.indd 18 H_and_Tourism_23_may.indd 18 24/05/2016 05:25 4/05/2016 05:25 and canoeing; cultural tourism; and visits to historic cities and buildings (UNWTO 2008). | Impacts | 20 - 21 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Despite the growing body of academic research demonstrating the risks posed to tourism by climate change, concern remains low among tourism operators, with many wrongly believing that there is too much uncertainty around climate impacts to justify action and that adaptation will be relatively easy (Nichols 2014). In fact, adaptation options at many destinations are quite limited and there is an urgent need for the industry to address the issue more seriously. A 2008 report from the UNWTO and UNEP noted that the policy changes and investments needed for effective adaptation may take decades to put in place. The report called on the tourism sector to urgently begin developing and implementing response strategies, especially for destinations most likely to be affected by climate change by mid-century (UNWTO 2008). A recent academic assessment of the implications of the latest climate science for the tourism sector concluded that “the political and business case for a sectoral response on climate change has never been stronger” and “tourism absolutely cannot afford not to ... dedicate increased efforts to understand the implications of climate change” (Scott et al. 2016). | Impacts | 21 - 21 |

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| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | However, there are often negative impacts associated with uncontrolled or unplanned tourism development, including a lack of visitor access management, cultural disruption and poorly planned infrastructure such as airports, cruise ship terminals and hotels. Such developments can contribute to local environmental problems including excessive water consumption, water pollution, waste generation, habitat damage and threats to local cultures and traditions (UNEP and UNWTO 2012). | Impacts | 23 - 23 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Tourists themselves can have a direct impact on sites, as is the case with visitors to Angkor in Cambodia (Delanghe et al. 2011) and scuba divers at Palau's Rock Islands Southern Lagoon (Poonian et al. 2010). Stonehenge in the UK now only allows access to a newly built visitors' centre rather than to the prehistoric site itself, so as to prevent damage to the stones; in France the famous Lascaux caves with their prehistoric paintings have been closed to tourists since 1963; and in Egypt, Tutankhamun's tomb will soon be closed and a replica built for tourists to visit instead. The last two sites have suffered significant deterioration caused by the humidity and temperature changes resulting from thousands of tourists entering their enclosed spaces. | Impacts | 23 - 23 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | World Heritage and tourism in a changing climate 21– The Historic Centre of Český Krumlov, Czech Republic, is one of many historic cities at risk from catastrophic flooding as a result of more extreme weather events in a changing climate. | Impacts | 23 - 23 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | WH_and_Tourism_23_may.indd 21 H_and_Tourism_23_may.indd 21 24/05/2016 05:25 4/05/2016 05:25<br>22 World Heritage and Tourism in a Changing Climate If allowed to develop too fast, in an unsustainable way or without proper attention to issues of social equity and local impact, tourism can undermine the very assets that people want to visit. In the worst cases, little or no social or economic benefit accrues to local communities and the integrity of a site's OUV can be threatened or degraded. | Impacts | 23 - 24 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | The World Heritage Centre's assessment of SOC reports received from States Parties in 1979–2013 (UNESCO 2014b) analysed three impact categories associated with tourism, and found that 26 per cent of the SOC reports identified impacts of "tourism/ visitor/recreation" as an issue, 14 per cent named "major visitor accommodation and associated infrastructure" and 10 per cent drew attention to problems caused by interpretation and visitation facilities. According to the analysis, the impacts of site visitor facilities are more often associated with cultural properties, whilst those of visitor accommodation and infrastructure occur more often at natural sites. "Tourism/visitor/recreation" problems were reported most frequently in the Asia Pacific and Europe/North America regions (UNESCO 2014b). | Impacts | 24 - 24 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Truly sustainable tourism development must manage issues of physical and cultural impacts at World Heritage sites and other destinations, as well as address the urgent necessity to reduce greenhouse gas emissions in this growing sector, especially from transport. At the same time, tourism should pay much greater attention to understanding and addressing the many and varied impacts of rapid climate change that will increasingly affect its operations and destinations. | Impacts | 24 - 24 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Table 1 illustrates the top 22 most reported impact categories at World Heritage sites for which SOC reports were submitted from 1979 to 2013 (UNESCO 2014b). | Impacts | 24 - 24 |

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| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | The formal and informal opportunities for women in the tourism sector can make a significant contribution to poverty reduction in rural communities and thereby increase community resilience to climate change and other stressors World Heritage and tourism in a changing climate 23– Management system/management plan Housing Legal framework Illegal activities Impacts of tourism/visitor recreation Ground transport infrastructure Financial resources Human resources Management activities Land conversion Identity, social cohesion, changes in local population and community Major visitor accommodation and associated infrastructure Water (rain/water table) Deliberate destruction of heritage Livestock farming/grazing of domesticated animals Mining Effects arising from use of transportation infrastructure Water infrastructure Interpretative and visitation facilities Solid waste Erosion and siltation/deposition War 0% 1–5% 6–10% 11–20% 21–30% 31–40% 41–60% 61–75% 76–100% Specific factor negatively affecting the outstanding universal value of the property Africa Arab World Asia�Pacific Europe and North America Latin America and Caribbean % of properties affected 84 51 29 27 24 27 14 24 29 20 20 16 16 20 10 2 14 8 10 16 14 14 77 32 22 26 32 27 20 15 23 10 11 12 10 10 1 12 10 10 14 4 3 0 58 38 18 9 25 20 8 7 15 3 2 13 7 8 1 8 8 6 10 6 4 1 75 43 41 22 29 28 26 21 21 21 21 21 12 9 15 6 18 12 6 4 6 0 Source: UNESCO 2014b (modified) 81 28 22 47 16 16 47 39 14 28 27 11 14 9 28 27 3 14 9 11 13 22 Table 1 The 22 most reported impact categories at World Heritage sites, 1979–2013 WH_and_Tourism_24_may.indd 23 24/05/2016 17:32<br>24 World Heritage and Tourism in a Changing Climate (UNWTO 2011). At the same time, however, climate-related damage to World Heritage sites can have a disproportionate economic effect on the women working in tourism. It is vital that the strategies and related tourism polices and measures implemented at World Heritage sites to address climate change be gender-responsive and support equality and empowerment. | Impacts | 25 - 26 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | ANALYSIS OF THE CASE STUDIES Twelve fully referenced case studies are presented in this report, selected for their value in demonstrating the broad variety of climate change impacts that World Heritage sites are exposed to across the WH_and_Tourism_23_may.indd 24 H_and_Tourism_23_may.indd 24 24/05/2016 05:25 4/05/2016 05:25<br>globe. Climate-related impacts already being experienced at these sites include glacier melt, loss of seasonal sea ice, sea-level rise, coastal flooding and erosion, more intense storms and storm surges, higher atmospheric and ocean temperatures, changes in wildfire regimes and weather patterns, extreme rainfall, water scarcity, falling lake levels, drought and desertification, thawing permafrost and changes in species distribution. | Impacts | 26 - 27 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | A number of the sites – including Greenland's Ilulissat Icefjord (Denmark); Shiretoko in Japan; the Ancient Ksour of Ouadane, Chinguetti, Tichitt and Oualata, Mauritania; the Rice Terraces of the Philippine Cordilleras; and the Heart of Neolithic Orkney (UK) – are already clearly being significantly and negatively affected by climate impacts. | Impacts | 27 - 27 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | At several of the sites where pressures resulting from visitor numbers, tourism development and infrastructure are already major stressors – including Rapa Nui National Park in Chile, the Galápagos Islands of Ecuador, the Italian city of Venice, and Ouadi Qadisha (the Holy Valley) and the Forest of the Cedars of God (Horsh Arz el-Rab) in Lebanon – climate change is an added problem, significantly increasing their vulnerability. Some of Concern is rising over the impact of mass tourism on fragile sites, including Angkor in Cambodia. | Impacts | 27 - 27 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | World Heritage and tourism in a changing climate 25– WH_and_Tourism_23_may.indd 25 H_and_Tourism_23_may.indd 25 24/05/2016 05:25 4/05/2016 05:25<br>26 World Heritage and Tourism in a Changing Climate the case studies and sketches profile sites where sustainable tourism or eco-tourism is an important part of national or local plans for economic development – such as Lake Malawi National Park, East Rennell in the Solomon Islands, and Coro and its Port in Venezuela – but where climate impacts threaten the success of those developments. | Impacts | 27 - 28 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Two of the case studies – the Statue of Liberty, USA and Venice and its Lagoon, Italy – demonstrate the scale of financial resources that will be required for increasing the resilience of many World Heritage sites in a changing climate. To date, US$ 100 million has been allocated to the Statue of Liberty and adjacent Ellis Island for the restoration of utilities, services and visitor facilities damaged by Hurricane Sandy in 2012, and to ensure preparedness for the storms that are predicted to continue to increase in intensity in future, with more damaging storm surges resulting from sea-level rise. In Venice, work is almost completed on a project to build gates to prevent flooding, costing more than US$ 6 billion. | Impacts | 28 - 28 |

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| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | In summary, several general conclusions regarding the interaction of climate change and tourism at World Heritage sites can be drawn from an analysis of the case studies: • climate change can have a major negative effect on the attractions and assets that draw tourists to World Heritage destinations and thereby reduce the potential for economic and sustainable tourism development; • over the long term the OUV, integrity and authenticity of some World Heritage sites could eventually be degraded by climate change to the extent that some properties may have to be added to the List of World Heritage in Danger and consideration eventually given to their de-listing; • at World Heritage sites where tourism infrastructure developments and uncontrolled or poorly managed visitor access are already a problem, climate change impacts – for example, extreme weather events, coastal flooding and erosion – are likely to exacerbate problems and increase site vulnerability; • climate change impacts have the potential to increase visitor safety concerns for the tourism industry, especially at sites where increased intensity of extreme weather events or vulnerability to floods and landslides are projected; • national and regional tourism and development strategies and site visitor management plans, with very few exceptions, currently fail to take climate change impacts into account; • climate change is too often regarded as a long�term potential problem for World Heritage sites rather than as an imminent or near-term issue, so assessment of climate vulnerability tends to be under-represented in state of conservation reports; • site managers often lack the financial resources and expertise or training necessary to undertake comprehensive climate vulnerability assessments and the development and implementation of adaptation and resilience strategies. | Impacts | 28 - 28 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | WH_and_Tourism_23_may.indd 26 H_and_Tourism_23_may.indd 26 24/05/2016 05:25 4/05/2016 05:25 Recommendations 27– T he situation analysis in this report, along with the case studies and site sketches, demonstrates the urgent need to understand, monitor and respond better to climate change threats to World Heritage sites, as well as the interactions between climate change and the tourism sector. The requirements of the binding Policy Document on the Impacts of Climate Change on World Heritage Properties that was adopted by the General Assembly of States Parties to the World Heritage Convention at its 16th session (Paris, 2007), as well as the 2006 Strategy to Assist States Parties to the Convention to Implement Appropriate Management Responses, should be fully implemented. Additional action should be taken to increase the resilience of cultural and natural heritage and reduce the impacts of both climate change and tourism. These recommendations are intended for the international community, States Parties, government policy makers, the tourism industry and site management authorities. | Impacts | 28 - 29 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | INTERGOVERNMENTAL ORGANIZATIONS, THE WORLD HERITAGE CONVENTION AND ITS STATES PARTIES The policy on responding to climate change adopted by the General Assembly of States Parties to the World Heritage Convention at its 16th session should be fully implemented The Policy Document on the Impacts of Climate Change on World Heritage Properties requires that States Parties “ensure they are doing all that they can to address the causes and impacts of climate change in relation to the potential and identified effects of climate change (and other threats) on World Heritage properties on their territories”. | Impacts | 29 - 29 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | States Parties are asked to consider site-level monitoring, mitigation and adaptation measures and establish thematic, global and regional links to understand, access, fund and implement mitigation and adaptation strategies. These efforts should be coordinated with other conventions and international bodies. States Parties should work to build public awareness and knowledge of climate change and its potential impacts on World Heritage properties and their values. The policy also calls for more research and research funding partnerships to better understand the consequences and costs of climate change for World Heritage sites as well as for societies, particularly traditional ones, or in sites such as cultural landscapes where the way of life contributes to their outstanding universal value (OUV). Consideration should be given to updating the World Heritage Committee’s Strategy to Assist States Parties to the Convention to Implement Appropriate Management Responses in the light of the most up-to-date knowledge on site vulnerability and management options, potential resilience strategies and the latest climate science. Research, including on climate change, should continue to inform the implementation of the convention and management responses. | Impacts | 29 - 29 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Identify those World Heritage sites most vulnerable to climate change and strengthen systems for continued assessment, monitoring and early warning of impacts Despite efforts to address gaps in knowledge, information and capacity, there is still a need to undertake a comprehensive global review of the climate vulnerability of World Heritage sites, identify those that are most at risk and assess the threat to their OUV, integrity and authenticity. | Impacts | 29 - 29 |

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| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | This review should take account of the interaction of climate change with existing stressors such as tourism pressures, illegal harvesting of natural resources, oil and gas developments, armed conflict and poverty. Systems for monitoring and early warning of climate change impacts should be developed and implemented. UNESCO, working with other international organizations including the United Nations Environment Programme (UNEP), United Nations Development Programme (UNDP), International Labour Organization Recommendations WH_and_Tourism_23_may.indd 27 H_and_Tourism_23_may.indd 27 24/05/2016 05:25 4/05/2016 05:25 28 World Heritage and Tourism in a Changing Climate (ILO), United Nations Industrial Development Organization (UNIDO) and the World Tourism Organization (UNWTO), should prioritize the mapping of impacts using World Heritage properties to field test management strategies and approaches in order to improve resilience and minimize impacts from climate change. | Impacts | 29 - 30 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | The World Heritage Committee should reinvest in implementing one of the key principles as defined by the Policy Document on the Impacts of Climate Change: to use existing tools of the World Heritage Convention and its operational guidelines, such as the List of World Heritage in Danger, and processes including reactive monitoring and periodic reporting, when considering the threat posed by climate change to the OUV, authenticity and/or integrity of a World Heritage property (UNESCO 2007). | Impacts | 30 - 30 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Make climate vulnerability assessment part of the World Heritage site nomination and inscription process Because of the potential for climate change to alter or significantly damage heritage values, climate change projections and vulnerability should be considered by States Parties when entering sites on to the Tentative List and when submitting their World Heritage nominations. In their evaluation of the nomination files put forward by the States Parties, the World Heritage Committee and its advisory bodies should also take climate change effects into account in accordance with the Policy Document on the Impacts of Climate Change. | Impacts | 30 - 30 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Include cultural heritage in climate vulnerability assessments and policy responses at all levels, from the local to the international Cultural heritage is not just a casualty of climate change; it is also a source of resilience and, therefore, part of the solution. Neither the WH_and_Tourism_23_may.indd 28 H_and_Tourism_23_may.indd 28 24/05/2016 05:25 4/05/2016 05:25 Recommendations 29– knowledge gained from living and past cultures, including from cultural heritage represented under the World Heritage system, nor the value of heritage lost or at risk of loss, has yet been effectively addressed in international scientific assessments of climate change such as the reports of the Intergovernmental Panel on Climate Change (IPCC) (UCSUSA 2014; INTO 2011). The IPCC should include and fully integrate cultural heritage in all future assessment reports. Cultural heritage and climate impacts on cultural World Heritage sites must also be more comprehensively addressed in climate policy responses. The 2014 Pocantico Call to Action on Climate Impacts and Cultural Heritage (UCSUSA 2014) and its call for mechanisms to ensure that cultural heritage voices and expertise are represented in climate policy discussions at all levels from the local to the international should be heeded. | Impacts | 30 - 31 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Analyse archaeological data and cultural heritage to use what can be learned from past human responses to climatic change to increase climate resilience for the future Some of the archaeological resources that can provide insights for our future by opening windows on the past are in danger of being lost, particularly in rapidly warming Arctic regions and along eroding coastal and riverine sites. An international response is needed to identify the sites most at risk and to synthesize and use lessons gleaned from the archaeological record and cultural heritage that can help with the development of adaptation strategies for natural and cultural heritage (IHOPE 2015; Jarvis 2014; Rockman 2012). | Impacts | 31 - 31 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | GOVERNMENT POLICY MAKERS AND THE TOURISM INDUSTRY Develop strategies and polices that lead to greenhouse gas emission reductions from the tourism sector that are in line with the goals of the Paris Agreement Carbon emissions from transportation and accommodation in the tourism sector are predicted to triple by 2035 and the paucity of technological mitigation options, especially for the rapidly growing long-haul travel sub-sector, means that emissions related to tourism are likely to continue to grow (Fischedick et al. 2014) unless sector-wide action is taken. The response from the industry needs to be on a scale that can match the seriousness and urgency of the problem (OECD 2011). The sector, including the travel and aviation industries, large international tour operators, small businesses, resorts and destinations, must address the issue of its emissions growth. Operators should audit, monitor and reduce their carbon emissions and minimize other environmental impacts. Sector-wide strategies and policies will require the development and adoption of less energy-intensive transportation and accommodation operations and the promotion of sustainable tourism. | Impacts | 31 - 31 |

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| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Create detailed climate change action strategies for tourism management and development at vulnerable sites Multi-stakeholder climate change strategies for tourism should be developed for sites where climate change has been identified as a current or future threat to their OUV, or where climate and tourism impacts together are increasing the vulnerability of the site and local communities. States Parties should work together with site management authorities, local communities, research institutions and the tourism industry to create strategies that: • raise awareness of the OUV of natural and cultural sites and their importance as key assets for the tourism sector; • provide a framework for the tourism industry to respond to climate change, including reducing their own carbon emissions; • engage tourism operators in action that contributes to stewardship in the context of a changing climate; • help to leverage resources in support of climate preparedness and resilience; • provide a coordinating mechanism for government and the tourism industry to address policy and management issues to ensure an adequate response to climate change. | Impacts | 31 - 31 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | WH_and_Tourism_23_may.indd 29 H_and_Tourism_23_may.indd 29 24/05/2016 05:25 4/05/2016 05:25 30 World Heritage and Tourism in a Changing Climate Fully integrate climate change impacts and preparedness into national and site-level tourism planning, policies and strategies The importance to tourism of preserving World Heritage sites in a changing climate must be emphasized, recognized and understood by all involved in tourism planning at the national level, and in the public and private sectors. The management of World Heritage properties for tourism needs to take climate change vulnerability and protection into account. The potential impacts of climate change on the value and integrity of World Heritage sites, as well as the interactions between climate and tourism that could exacerbate negative effects, should be fully considered and integrated into national, regional and local tourism strategies and management. The current lack of integrated cross-sectoral assessments that analyse the full range of potential impacts and their interactions needs to be addressed urgently (Scott et al. 2016). | Impacts | 31 - 32 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Site management plans should closely reflect the predicted operational risks and potential impacts of both climate change and tourism. | Impacts | 32 - 32 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Develop management tools for collecting data on tourism and climate impacts It is important to develop tools for evaluating the role of heritage and its enhancement in the context of tourism planning and development; to assess the socio-economic cost of the degradation of heritage values and heritage assets resulting from tourism and climate impacts; to help define and test best practices to ensure the long-term preservation of the cultural and economic resource; and to facilitate combined tourism development and climate impact assessment. | Impacts | 32 - 32 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Implement polices and action on climate change and tourism that are gender-responsive and participatory Women should have an equal voice in decision making on climate change responses as well as equal access to resources (Perry and Falzon 2014) and economic opportunities in the context of World Heritage management and sustainable tourism. Achieving gender equality and women's empowerment in tourism will increase community resilience to climate impacts (UNESCO 2014). The public and private sectors must take proactive steps to mainstream gender in tourism policy, planning and operations; protect women's rights; and facilitate women's education, leadership and entrepreneurship in tourism (UNWTO 2011). In the preparation of nominations for World Heritage listing, site managers, local communities, national agencies and other stakeholders should document and analyse the experience of women and men in relation to the sites and work together to identify and understand appropriate issues related to gender equality. | Impacts | 32 - 32 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | SITE MANAGEMENT AUTHORITIES, INDIGENOUS PEOPLES AND LOCAL COMMUNITIES Fully incorporate the latest climate science and innovation in adaptation strategies into World Heritage site management planning World Heritage site management plans should also incorporate climate research in decisions on planning and implementation relating to the sustainability of sites and their OUV. Tourism management and development strategies should be science-based and make use of the latest data on climate change impacts, vulnerability and resilience. There is also an urgent need to incorporate and better understand the climate exposure and sensitivity of OUV in all World Heritage sites and to incorporate arrangements for climate change adaptation and resilience into management strategies, especially at the most vulnerable sites. UNESCO has developed a methodology to guide development of climate change adaptation strategies and plans at World Heritage sites (Perry and Falzon 2014). Experience gained and lessons learned in implementing these guidelines at site level, as well as from innovative strategies for adaptation and resilience-building being developed by States Parties, will be invaluable. | Impacts | 33 - 33 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Ensure that effective risk reduction, disaster response and preparedness strategies are in place, and are updated regularly utilizing the latest climate science Climate-related disasters such as severe storms, extreme rainfall events, floods, landslides, droughts and wildfires present a growing threat to the integrity of vulnerable World Heritage sites. | Impacts | 33 - 33 |

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| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Properties should have effective risk-reduction and disaster-response plans with action priorities in place, and update them regularly based on the latest climate change science. UNESCO's resource manual on managing disaster risks provides valuable guidance for managers and management authorities of cultural and natural World Heritage properties to help reduce the risks to these properties from natural and human-induced disasters (UNESCO 2010). Over the long term, management authorities should shift from planning primarily for disaster response and recovery, to strategies that focus on Recommendations 31– Over at least 2 000 years, the Ifugao people of the Philippines have created a productive landscape of exceptional beauty, but the Rice Terraces of the Philippine Cordilleras are now threatened by climate impacts and cultural change. | Impacts | 33 - 33 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | For site risk assessment, it is important to evaluate the widest possible range of impacts, including low�probability outcomes with large consequences (IPCC 2014). Site conservation and management strategies should recognize the inherent potential of sites to reduce disaster risk and adapt to climate change through ecosystem services (Osipova et al. 2014; Renaud and Sudmeier-Rieux 2013; Temmerman et al. 2013). Many World Heritage sites include habitat and ecosystems that serve as natural buffers against climate impacts and other disasters, or play a major role in climate mitigation as carbon stocks and sinks. | Impacts | 34 - 34 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Around the world, cultural traditions and indigenous knowledge are being lost. These traditions, vitally important in themselves and also often a significant part of the tourism experience, can be damaged, degraded or lost as a result of both tourist contact and climate impacts. It is crucial to arrest this decline and ensure that adaptation and resilience efforts aimed at preserving World Heritage fully incorporate local voices and maximize the use of local and traditional knowledge. UNESCO, through its Local and Indigenous Knowledge Systems (LINKS) programme, has already gained valuable experience in this field that could be leveraged to benefit the management of World Heritage sites. | Impacts | 34 - 34 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Establish targeted programmes to raise awareness among tourists, guides, site managers and local communities about the values and protection needs of World Heritage in a changing climate Tourists visiting World Heritage sites represent an important target audience for awareness raising about climate impacts, adaptation and mitigation. | Impacts | 34 - 34 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | High-quality interpretive materials and programmes can enhance awareness of the risks posed to cultural heritage, wildlife and natural ecosystems from climate change as well as adaptation strategies. Learning about climate change in the locale where its effects are being felt can be a powerful catalyst. Training for tour operators, guides and park rangers can have a magnifying effect. UNESCO's 2009 Strategy for Action on Climate Change identified enhancing public education and awareness about climate change, including encouraging the adoption of sustainable behaviours as a key strategic priority (UNESCO 2009). Innovative programmes involving visitor education and ranger training that could serve as models are being developed by the National Park Service in the USA (USNPS Online). | Impacts | 34 - 34 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | WH_and_Tourism_23_may.indd 35 H_and_Tourism_23_may.indd 35 24/05/2016 05:25 4/05/2016 05:25 36 World Heritage and Tourism in a Changing Climate In addition to human-caused deforestation, habitat loss and degradation, there is a risk that climate change, together with the expansion of tourism, will increase the probability of disease passing from humans to gorillas. Mountain gorillas are closely related to humans and therefore particularly vulnerable to human diseases. So, whilst tourism has brought many benefits for gorilla conservation and local communities, the proximity of gorilla families that are habituated to tourists increases their risk of exposure to diseases, some of which may be new to them. In Bwindi, habituated gorilla groups have been shown to have a higher incidence of parasites and bacterial infections than non-habituated groups (Kalema-Zikusoka et al. 2005). Even without tourism, however, the habitat overlap between gorillas and people around Bwindi, where there is a dense matrix of agriculture and settlements, has already increased the likelihood of gorillas being infected. | Impacts | 37 - 38 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Its ruins, many of which remain unexcavated, are largely built of coral and limestone mortar, and it is perhaps best know for the Great Mosque, first built in the 11th century, and the palace of Husuni Kubwa. Coastal flooding and erosion are major threats to Kilwa Kisiwani as sea levels rise due to climate change and the city's vulnerability to damaging storm surges grows. | Impacts | 38 - 38 |

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| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | (WTTC 2015; UNESCOa) WH_and_Tourism_23_may.indd 36 H_and_Tourism_23_may.indd 36 24/05/2016 05:25 4/05/2016 05:25 Africa 37– and this particularly small gorilla group was more susceptible to infection because of stress from being tracked and viewed by tourist groups (Kalema-Zikusoka et al. 2002). If climate change causes increases in poor health amongst human populations around the park, which, for example, has been suggested as likely for a marginalized and poor local Batwa community (Berang-Ford et al. 2012), this could increase the risk of human-to�gorilla transmission of infections. Pioneering efforts, such as those of the NGO Conservation Through Public Health, to increase community heath and awareness in local villages and track gorilla health in order to reduce the risk of disease transmission and outbreaks are important, and several have been successfully under way for a number of years. | Impacts | 38 - 39 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | However, tourist impacts must be closely monitored and assessed in the light of climate change, which is expected to increase direct stresses on gorillas and their habitat as well as exacerbate the health risks gorillas face from tourism. | Impacts | 39 - 39 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Fire regimes are expected to continue to change, with greater frequency of fires predicted (Kraaij et al. 2013b). One impact of increased fire frequency would be a reduction in the height of the overall vegetation structure, with large proteas being replaced by grasses and fire ephemerals (Lee and Barnard 2015). | Impacts | 41 - 41 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | An internationally commercially important endemic plant species of the fynbos is rooibos (Aspalathus linearis), which is used to make redbush tea, a herbal drink growing in popularity worldwide, especially in Germany, Japan, the UK and USA. Rooibos was mainly harvested wild but is increasingly being grown commercially in Western Cape Province, where the tea industry provides employment for more than 5 000 people on farms and in factories, and turns over Lake Malawi National Park, Malawi, 1984 (vii), (ix), (x) At the southern end of Lake Malawi, one of the world's deepest freshwater bodies, Lake Malawi National Park is a prime, small-scale ecotourism destination. Tourists come for the scuba diving in the clear lake waters and to kayak and hike. The lake has the world's greatest diversity of freshwater fish with over 1 000 species, more than 350 of which are endemic cichlids (Cichlidae). The fish and ecosystems of Lake Malawi are increasingly at risk from a combination of climate change, human population pressure and deforestation. | Impacts | 42 - 42 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Water resources for agriculture and energy production are also at risk. (Kumambala and Ervine 2010; UNESCO c) WH_and_Tourism_23_may.indd 40 H_and_Tourism_23_may.indd 40 24/05/2016 05:26 4/05/2016 05:26 Africa 41– in excess of ZAR 500 million (c. US$ 31 million) annually (SADAFF 2014). The extensive expansion of rooibos cultivation in recent years has been a significant driver of the conversion of natural habitat to small farming operations. Models suggest, however, that the range of both wild and commercial rooibos will shrink significantly as the climate warms and the region dries. | Impacts | 42 - 43 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Aside from its incredible plant diversity, the fynbos provides important habitat for many bird species, including six endemic species. Climate projections suggest a significant loss of climatically suitable habitat for these endemic birds, including the protea canary (Serinus leucopterus) and Victorin's scrub-warbler (Bradypterus victorini), while the Cape rock-jumper (Chaetops frenatus) has already been nationally listed with near-threatened status as a consequence of its vulnerability to climate change (Lee and Barnard 2015). Estimates of climate impacts on bird populations that look only at range shifts may underestimate extinction risk. Modelling that takes into account changes in abundance as well as in range generally shows greater population impacts (Huntley et al. 2012). | Impacts | 43 - 43 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Any resulting loss in fynbos species diversity could have major implications, especially if the projected reductions in range and abundance occur for such important pollinators as the orange-breasted sunbird (Anthobaphes violacea) and Cape sugarbird (Promerops cafer) (Huntley and Barnard 2012). | Impacts | 43 - 43 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | The importance of refugia Climate change is projected to reduce the Cedrus libani populations to only three refugial zones by 2100, due to higher temperatures and water stress from decreased moisture availability in the Mediterranean region (Hajar et al. 2010a). While plant communities can adapt to climate change by WH_and_Tourism_23_may.indd 43 H_and_Tourism_23_may.indd 43 24/05/2016 05:26 4/05/2016 05:26 44 World Heritage and Tourism in a Changing Climate migrating to higher altitudes through seed dispersal and gradual replacement, most of the cedar forests of Lebanon are already isolated on or near mountain summits, with nowhere further upslope to go. The Arz el-Rab stand in the Qadisha valley is an exception, being one of the three cedar forests where there is higher-altitude habitat available for potential migration, which makes their protection all the more urgent (Hajar et al. 2010a). The cedars of Ouadi Qadisha exemplify the vulnerabilities and loss of resilience that plant communities face with habitat degradation and fragmentation. | Impacts | 45 - 46 |

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| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Ancient Ksour of Ouadane, Chinguetti, Tichitt and Oualata, Mauritania, 1996 (iii), (iv), (v) The medieval desert caravan towns (ksour) of Mauritania were important trade and cultural centres on the trans-Saharan caravan routes for more than seven centuries. Chinguetti, famous for its square-towered mosque built of un�mortared stone, is the seventh most holy city of Islam and along with the other ksour is an important historic attraction for visitors bringing much-needed income to local residents. Tourism in Mauritania is very underdeveloped, and has been hampered in recent years by concerns over travellers' security. Mauritania's ksour, once centres of nomadic and Islamic culture in North Africa, are now threatened by the encroaching Sahara. The streets and courtyards of Chinguetti, known for its ancient libraries of Islamic books and manuscripts, are being inundated by sand as dunes migrate into the city. Extreme heat can damage ancient masonry while intense rainstorms threaten earthen architecture and worsen soil erosion problems. Desertification in Africa's Sahel region exacerbates the problem, and its causes are complex, including land-use issues such as overgrazing, deforestation and urbanization, further complicated by climate change. Extended severe droughts and more extreme rainfall events are adding to existing development pressures and resource conflicts. (UNESCO c; USAID 2012; Brimblecombe et al. 2011) WH_and_Tourism_23_may.indd 45 H_and_Tourism_23_may.indd 45 24/05/2016 05:26 4/05/2016 05:26 46 World Heritage and Tourism in a Changing Climate Rock Islands Southern Lagoon, Palau, 2012 (iii), (v), (vii), (ix), (x) This culturally and biologically rich Western Pacific site extends over more than 100 000 hectares and consists of more than 400 limestone islands, many surrounded by lagoons and coral reefs. The Rock Islands contain the highest concentration of marine lakes anywhere in the world. The site harbours nearly 400 coral species, a great deal of habitat complexity and a high level of species endemism. Although uninhabited today, the remains of abandoned stone villages, including defensive walls and subsistence farming terraces on some of the larger islands, date back some 500–950 years. Ancient rock art, burials and middens provide evidence of occupation over a period of 5 000 years, and archaeologists have been able to demonstrate human use of marine resources over more than 3 000 years. The area holds great cultural significance for modern-day Palauans and its use is regulated through a system of traditional governance. With a population of around 21 000, Palau received 160 000 tourists in 2015 (more than half of them from China), a three-fold increase in just 15 years. Scuba diving and snorkelling are major recreational attractions for visitors and Palau's marine habitats are regarded as among the world's best diving sites. | Impacts | 47 - 48 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | However, pollution associated with rapid tourism infrastructure growth and physical damage to corals from poorly controlled diving and snorkelling are increasing the risk of degradation to Palau's marine habitats. Coral cover worldwide has decreased markedly in recent decades due to a combination of factors including pollution and sedimentation from coastal development, overfishing and disease, but concern is greatest over the impacts of climate change, including in Palau. Rising temperatures in tropical and sub-tropical waters in recent decades have pushed many corals to the limits of their thermal tolerance, and the Southern Lagoon experienced significant coral bleaching in 1998, 2010 and then again in 2015. Worldwide, ocean acidification is occurring as a direct result of seawater absorbing more carbon dioxide from the atmosphere, a change in ocean chemistry that interferes with the ability of corals to build strong calcium carbonate skeletons. Some of the marine lakes of Rock Island Southern Lagoon are naturally acidic, with pH levels close to those projected for the western tropical Pacific open ocean by 2100. | Impacts | 48 - 48 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Therefore the site provides a unique natural laboratory that may help scientists gain insights about coral reef resilience in the face of global warming and ocean acidification. (UNESCOa; Republic of Palau; Shamberger et al. 2014; Poonian et al. 2010; Hoegh-Guldberg et al. 2007) WH_and_Tourism_23_may.indd 46 H_and_Tourism_23_may.indd 46 24/05/2016 05:26 4/05/2016 05:26 Asia and the Paciff c 47– Hoi An Ancient Town, Viet Nam, 1999 (ii), (v) Situated on the banks of the Thu Bon River in Viet Nam's central Quang Nam province, Hoi An is an exceptionally well-preserved example of a Far Eastern trading port that was active from the 15th to the 19th centuries. The old town has more than 1 100 wood-framed buildings, 800 of which date from the 16th and 17th centuries. Tourism is the main economic activity in the city and has surged since its listing as a World Heritage site, with the average number of tourists increasing by 20 per cent year on year from 2003 to 2010. The city is prone to flooding during the annual rainy season, but climate change is expected to worsen conditions considerably in the future. Much of An Hoi is at or no more than 2 metres above sea level, so is vulnerable to sea-level rise, storm surges during typhoons, and coastal erosion. Nearby Cui Dai beach – a major draw for tourists and high�end tourism development – is already losing between 10 and 20 metres of land to erosion annually. Virtually the whole of the An Dinh district, the area of Hoi An with most of the heritage houses, could be flooded annually by 2020 according to a recent UN-Habitat vulnerability assessment. (UN-Habitat 2014) Shiretoko, Japan, 2005 (ix), (x) The extraordinarily productive marine ecosystems of Shiretoko in Hokkaido Province of Japan are directly linked to the formation of the southernmost sea ice in the northern hemisphere. The sea ice drives the production of phytoplankton in the early spring, in turn supporting salmon and trout (Salmonidae), which swim up the rivers, linking the terrestrial habitats and providing food for species including brown bear (Ursus arctos) and Blakiston's fish owl (Bubo blakistoni). | Impacts | 48 - 49 |

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| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | (UNESCOb; Makino and Sakurai 2012; WWF-Japan) WH_and_Tourism_23_may.indd 47 H_and_Tourism_23_may.indd 47 24/05/2016 05:26 4/05/2016 05:26 48 World Heritage and Tourism in a Changing Climate Sagarmatha National Park, Nepal, 1979 (vii) Encompassing the highest point on Earth – the peak of Mount Everest at 8 848 metres – Sagarmatha National Park is listed as a World Heritage site for the exceptional natural beauty of its landscapes of mountains, glaciers and deep valleys. Sagarmatha is home to a vibrant Sherpa culture that blends traditional agricultural practices with a deep reverence for nature. The park's diverse ecosystems provide sanctuary for the endangered snow leopard (Panthera uncia) and red panda (Ailurus fulgens), and draw tourists from across the globe for trekking and mountaineering. One third of the people on Earth depend on water that flows from the Himalayas, including from Sagarmatha. This water resource is now being jeopardized, however, as warming temperatures and changes in precipitation are causing Himalayan glaciers to retreat and altering patterns of water run-off. A loss of glaciers can also destabilize surrounding slopes, resulting in catastrophic landslides, and excessive meltwater can cause glacial lake outbreaks or flash floods and erosion. If snow and ice accumulation does not match accelerated glacial melting, water shortages will affect millions of people downstream in the future. (UNESCO d) Komodo National Park, Indonesia,1991 (vii), (x) The islands of Komodo National Park contain extremely biodiverse ecosystems including mangroves, coral reefs, dry savannah and tropical forest, but they are most famous for the Komodo dragon (Varanus komodoensis), the largest living species of lizard and one that exists nowhere else on Earth. More than 60 000 international tourists visited the park in 2013 to see the Komodo dragons, a 20 per cent increase in numbers from 2012. There are not many more than 5 000 lizards in the national park, and, as often happens with such isolated island populations, they are particularly vulnerable to environmental change. Increased rainfall associated with climate change in the very dry Komodo islands could inundate lizard breeding areas and change the vegetation to habitats that are less hospitable to them. | Impacts | 49 - 50 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Meanwhile, ocean acidification and warming temperatures pose a threat to the islands' wonderful coral reefs and sea-level rise is putting mangrove forests at potential risk. | Impacts | 50 - 50 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Under these circumstances, tourist numbers and infrastructure development need to be managed with great sensitivity in order to prevent damage to the local ecosystems or additional stress on the Komodo dragons. | Impacts | 50 - 50 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | (UNESCO c; Nuwer 2012; Holland 2014) WH_and_Tourism_23_may.indd 48 H_and_Tourism_23_may.indd 48 24/05/2016 05:26 4/05/2016 05:26 Asia and the Paciff c 49– Lagoons of New Caledonia: Reef Diversity and Associated Ecosystems (France), 2008 (vii), (ix), (x) The World Heritage site includes several protected areas which together cover more than 1.5 million hectares of the most important marine and reef ecosystems of the French islands of New Caledonia in the Western Pacific. New Caledonia's coral reef is one of the three most extensive reef systems in the world and has the greatest diversity of reef structures to be found anywhere. A relatively healthy reef and preserved ecosystem, it has an exceptional diversity and abundance of benthic and pelagic communities, many top predators and large fish as well as globally important populations of dugongs (the second largest world population), turtles and seabirds. New Caledonia receives about 100 000 tourists every year, many of whom come for the diving and extraordinary natural beauty of the lagoon and reef environment. New Caledonia is the world's third biggest source of nickel, and there have been concerns for the health of its marine ecosystems after more than a century of mining operations have resulted in mountainside erosion, sedimentation and pollution in lagoon waters. Climate change is projected to exacerbate the effects of non-climate stresses such as these, as well as overfishing and any impacts associated with future tourism developments. Climate impacts including increased water temperature and ocean acidification are now the biggest threat to coral reefs worldwide. Coral bleaching is mainly triggered by rapid and prolonged increases in water temperatures. This stressful condition for corals results in the colourful symbiotic algae that live in their tissues – and on which they rely for nutrition – being expelled, turning the corals white. Higher ocean temperatures driven by climate change, combined with major El Niño events, caused extended coral bleaching and die-offs around the globe in 1998, 2010 and again in 2015–2016. In New Caledonia, bleaching has so far been restricted to local events – with the notable exception of a 1995–1996 event reported by researchers from France's Institut de recherche pour le développement (IRD). In February 2016, however, marine biologists and oceanographers from the IRD called the alarm on unprecedented mass bleaching on the islands' reefs, and they are currently studying the phenomenon to evaluate its extent and ascertain the causes. | Impacts | 50 - 51 |

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| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | (UNESCOe; World Bank; IRD 2016, 2011; NOAA 2015; Gattuso 2014; Pew Charitable Trusts 2015) WH_and_Tourism_23_may.indd 49 H_and_Tourism_23_may.indd 49 24/05/2016 05:26 4/05/2016 05:26 50 World Heritage and Tourism in a Changing Climate Rice Terraces of the Philippine Cordilleras, Philippines, 1995 (iii), (iv), (v) The indigenous Ifugao people of the Philippine Cordilleras have built and developed their rice terraces over a period of at least 2 000 years. This exceptionally beautiful and important cultural landscape, which draws tourists from all over the world, is highly sensitive to climate change and is already suffering negative effects. Warming temperatures and increases in extreme rainfall events are major problems. More intense rainstorms will increase the instability of the rice terraces built on steep mountain slopes, and cause landslides and erosion. An additional problem is that local rice varieties developed over hundreds of years under stable climatic conditions by the Ifugao are less adaptable to rapid climate change than modern rice strains. Climate change comes on top of cultural perturbations that include the abandonment of rural tradition by young people who are increasingly moving to urban areas. (Manila Observatory; UNESCO f; Katutubo 2015) East Rennell, Solomon Islands, 1998 (ix) Covered in dense tropical forest, Rennell Island is the southernmost of the Solomon Islands in the Western Pacific, and the largest raised coral atoll in the world. The East Rennell World Heritage site comprises 37 000 hectares at the south of the island. The protected area includes the brackish Lake Tegano, the largest lake on any Pacific island. About 1 200 people live in four villages within the property's boundaries and East Rennell was the first World Heritage site to be inscribed with responsibility for its management lying with the traditional and customary owners. East Rennell's outstanding value lies in its undisturbed ecosystems and ecological processes, which make it a natural laboratory for the study of evolution and island biogeography. The integrity of the site as well as its nascent low-impact ecotourism potential are now under threat from commercial logging, the introduction of alien species including the black rat (Rattus rattus), and climate change. Warming-induced sea-level WH_and_Tourism_23_may.indd 50 H_and_Tourism_23_may.indd 50 24/05/2016 05:26 4/05/2016 05:26 Asia and the Paciff c 51– rise is directly affecting Lake Tegano, raising its water levels and salinity. As a result, coconut and taro crops, vital food staples for the local communities, have been significantly reduced, and houses, tourist lodges and the school have been flooded. (UNESCO g) Golden Mountains of Altai, Russian Federation, 1998 (ix) Although the Altai Mountains of Russia were originally listed as a World Heritage site for its biodiversity values, the region is equally important for its incredible cultural and archaeological treasures. | Impacts | 51 - 53 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | The lakes and wetlands of Yellowstone are also changing, with warmer and drier conditions causing them to shrink in some parts of the park. Scientists estimate that 40 per cent of the wetlands in the Greater Yellowstone Ecosystem could be lost under these conditions; at particular risk are seasonal wetlands and the species that depend on them. | Impacts | 56 - 56 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Chorus frogs (Pseudacris maculata) may be under threat since they rely on shallow and ephemeral ponds, while moose (Alces alces), trumpeter swans (Cygnus buccinator) and sandhill cranes (Grus canadensis) are also highly vulnerable to the loss of wetlands (Ray et al. 2015). | Impacts | 56 - 56 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | While fire is a major factor for the forest ecosystems of Yellowstone, changes in temperature can also have a direct impact on their distribution. The tree line is likely to move upslope, and species from lower elevations including sagebrush (Artemisia tridentata var. vaseyana) and juniper (Juniperus communis var. depressa) communities may well expand their ranges. Meanwhile, suitable habitat for high mountain species such as Engelmann spruce (Picea engelmannii) and whitebark pine (Pinus albicaulis) is likely to be much reduced and severely restricted (Hansen et al. 2015). | Impacts | 57 - 57 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | An indicator for wider impacts Yellowstone can be a useful indicator for climate impacts on large ecosystems. With good habitat connectivity it is well buffered from most other environmental stresses, but it will still change – probably quite extensively – under evolving climatic conditions, perhaps even losing some of its iconic species and landscape characteristics. | Impacts | 57 - 57 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Climate change impacts will undoubtedly alter the visitor experience though, and if there are more frequent closures for forest fires, reduced potential for fishing or loss of iconic species and landscape features, the tourism economy may suffer (Riginos et al. 2015). Yellowstone National Park will continue to draw millions of tourists a year for generations to come, but it can also provide a vital natural laboratory for the study of climate change, as well as an outdoor classroom in which to educate and engage visitors about the problem and its solutions. | Impacts | 57 - 57 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Hurricane Sandy – an unprecedented event As solid and invulnerable as the Statue of Liberty itself seems, the World Heritage site is actually at considerable risk from some of the impacts of climate change – especially sea-level rise, increased intensity of storms and storm surges. In October 2012, flood waters from Hurricane Sandy inundated 75 per cent of Liberty Island and although the statue and its pedestal were not harmed or flooded, extensive damage was caused to facilities and infrastructure. | Impacts | 59 - 59 |

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| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Together with Ellis Island, the cost of damage from the hurricane exceeded US$ 77 million (Cascone 2015; NPS 2013). | Impacts | 59 - 59 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | The impacts of this "super-storm" were very significantly exacerbated by local sea-level rise of more than 0.5 metres since records began in the 1850s (Holtz et al. 2014). The amplifying effects of rising sea levels mean that storms of lower and lower intensity will cause more storm surge damage in the future. At the same time, rising upper-ocean temperatures in the North Atlantic – temperatures that are projected to continue to rise – are expected to increase the intensity of hurricanes (Sweet et al. 2013). | Impacts | 59 - 59 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | The cost of all the damage caused by Hurricane Sandy was in excess of US$ 60.2 billion and, although this was a once-in-700-year storm, global warming and sea-level rise are likely to drastically increase the likelihood of this kind of WH_and_Tourism_23_may.indd 57 H_and_Tourism_23_may.indd 57 24/05/2016 05:26 4/05/2016 05:26 58 World Heritage and Tourism in a Changing Climate storm and its impacts in the future (Sweet et al. | Impacts | 59 - 60 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Lessons learned A 2015 vulnerability analysis carried out by the US National Park Service on its coastal properties concluded that 100 per cent of the assets at Liberty National Monument are at "high exposure" risk from sea-level rise due to the extremely low elevation of the island and its vulnerability to storms. The assets at risk on Old Town Lunenburg, Canada, 1995 (iv), (v) Lunenburg on the southern coast of Nova Scotia is the best example of a planned British colonial settlement townscape in North America. Since its establishment in 1753, Lunenburg has been dependent on its waterfront and the North Atlantic for its main industries of fishing, shipping, ocean commerce and now tourism. | Impacts | 60 - 60 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | More than 1.8 million tourists visit Nova Scotia annually and tourism revenue on the south coast exceeds CAD $ 160 million (c. US$ 115 million) a year, with Lunenburg being one of the top destinations. Rising seas threaten to inundate some coastal land permanently, and higher water levels will also result in more damage from storm surges and flooding in parts of the Old Town that have not previously been affected. Many buildings and roads are vulnerable, and among those most at risk is one of Lunenburg's major tourist attractions, the Fisheries Museum of the Atlantic, housed in a complex of historic buildings on the waterfront. | Impacts | 60 - 60 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | (Forbes and Wightman 2013; UNESCO c) WH_and_Tourism_23_may.indd 58 H_and_Tourism_23_may.indd 58 24/05/2016 05:26 4/05/2016 05:26 North America 59– Liberty and Ellis Islands, including the Statue of Liberty itself, are valued at more than US$ 1.5 billion (Peek et al. 2015), but the intangible cost of future damage to this international symbol of freedom and democracy is incalculable. | Impacts | 60 - 61 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Hurricane Sandy's damage to the infrastructure of the Statue of Liberty World Heritage site was extensive and tourism to one of the most popular attractions in the USA had to close for many months, but the lessons learned from its recovery can provide a model for other vulnerable coastal sites. | Impacts | 61 - 61 |

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| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Temperatures are rising in Mesa Verde and it has been warmer since 1950 than at any time in the past 600 years. Annual rainfall is declining and so too is stream flow in the park. As in much of the western USA, hotter drier conditions are leading to a longer wildfire season and greater number of large wildfires. Mesa Verde's 4 500 archaeological sites are under severe threat of irreversible damage both from the increasing wildfires and from the flash floods and erosion that often follow. The vulnerability of Mesa Verde's cultural assets to climate change could have a negative effect on tourism in the park, which attracts about 500 000 visitors a year contributing about US$ 47 million to the local economy. Damage to archaeological sites and the iconic cliff dwellings could change this, as could more frequent park closures due to large wildfires. (Holtz et al. 2014) WH_and_Tourism_23_may.indd 59 H_and_Tourism_23_may.indd 59 24/05/2016 05:26 4/05/2016 05:26 Port, Fortresses and Group of Monuments, Cartagena, Colombia Date of Inscription: 1984 Criteria: (iv), (vi) Significance: colonial buildings and military architecture of the 16th, 17th and 18th centuries; history of world exploration and maritime trade WH_and_Tourism_23_may.indd 60 H_and_Tourism_23_may.indd 60 24/05/2016 05:26 4/05/2016 05:26 Latin America 61– F ounded in 1533, Cartagena de Indias has one of the most extensive and complete complexes of military fortifications in South America. Strategically located on the northern and Caribbean coast of Colombia, the city played a central role in the struggles between European powers competing for control of the "New World" in the 16th, 17th and 18th centuries. The city was a central hub for maritime trade in the West Indies and offers a rich history and legacy of colonial architecture to its visitors. Today, nearly 500 years after the Spanish conquest of Colombia's Caribbean coast, Cartagena is enjoying a tourist boom that is bringing jobs and economic revitalization to the region. Rapid sea-level rise and coastal flooding, however, are putting these developments at risk. | Impacts | 61 - 63 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | WH_and_Tourism_23_may.indd 61 H_and_Tourism_23_may.indd 61 24/05/2016 05:26 4/05/2016 05:26 62 World Heritage and Tourism in a Changing Climate The average sea-level rise for the Caribbean basin was approximately 2.5 millimetres a year from 1993 to 2010, consistent with global trends. The rate of rise at Cartagena, however, has been more than twice the Caribbean average due to local factors, especially land subsidence, probably caused by extensive urbanization, and has averaged 5.3 millimetres a year over the same period (Torres and Simplis 2013). Increased frequency and intensity of storms and inadequate urban drainage and storm-water systems amplify the risks from climate change (Adams and Castro 2013). | Impacts | 63 - 64 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Through all of its nearly 500-year history, Cartagena has been inextricably tied to the sea. The city now faces its greatest modern challenge as a result of accelerated sea-level rise, coastal flooding and shoreline erosion. Its sprawling squatter settlements and poorest neighbourhoods are on the front-line of climate change and the historic colonial centre that attracts tourists, creates jobs and keeps the economy growing is under threat. | Impacts | 64 - 64 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | The walls, parapets, forts and buildings that comprise the World Heritage site are subject to varying degrees of risk. For example, a recent UNESCO assessment identified the Fort of San Fernando as being affected by erosion, sedimentation and waves but that it had not yet been seriously affected. In contrast, the Fort of San Jose has already been significantly damaged and undermined by waves and erosion, putting its future in question (UNESCO 2014). | Impacts | 64 - 64 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Plan 4C provides a road-map for planning climate�compatible development so that the city is prepared for climate impacts by 2040 and is able to continue to boost economic development – including industry, maritime trade and tourism – while maintaining its historic buildings and monuments in the face of accelerating climate change (Zamora-Bornachera 2014). | Impacts | 65 - 65 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Coro was put on the List of World Heritage in Danger in 2005 as a result of significant damage caused by unusually intense rain and storms in 2004 and 2005. The Central America and Caribbean region has been identified as one of the tropical parts of the world most responsive to climate change, and has experienced a marked increase in extreme weather events including droughts, storms and floods over the last 30 years. Increased intensity of periodic rainstorms presents the primary threat to the historic buildings of Coro and La Vela, causing roof leaks, erosion of mud-roof mortar, structural cracking, damp walls, wall collapses and landslides. Major strides in addressing these problems have recently been made through collaborative efforts involving the state, community and traditional artisans. There are positive signs that proactive adaptation strategies can help maintain this important heritage and tourism resource under changing climate conditions. (UNESCOa) WH_and_Tourism_23_may.indd 63 H_and_Tourism_23_may.indd 63 24/05/2016 05:26 4/05/2016 05:26 Athousand kilometres off the coast of Ecuador, at the confluence of three Pacific currents, lie the Galápagos Islands, an archipelago of 18 large islands, three smaller ones and more than 100 islets and rocks that are home to a remarkable diversity of species (UNESCOb). | Impacts | 65 - 66 |

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| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | The main threats to the biodiversity of the Galápagos Islands in recent decades have been tourism and population growth, the introduction of alien and invasive species, and illegal fishing (UNESCOb). Now climate change is also having an impact, and represents a new threat that will exacerbate some of these problems and bring new issues to the fore. Climate concerns relate to impacts resulting from global trends of rising sea levels, warming oceans and atmosphere, ocean acidification and changes in rainfall and extreme events, all of which can have negative consequences for the islands' ecosystems. | Impacts | 67 - 67 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | WH_and_Tourism_23_may.indd 65 H_and_Tourism_23_may.indd 65 24/05/2016 05:26 4/05/2016 05:26<br>66 World Heritage and Tourism in a Changing Climate Particularly severe El Niño events, such as those experienced in 1982–1983 and 1997–1998, can have devastating impacts on Galápagos species as food supplies are disrupted. The severe weakening of the Equatorial Undercurrent associated with El Niño affects the entire food web, with warmer waters reducing the upwelling of nutrients that usually characterizes the cold waters around the Galápagos, resulting in a reduction in phytoplankton availability and causing small fish and invertebrates to migrate away, as well as reducing the growth of algae on which many species rely. As a consequence, the extreme El Niño events of the 1980s and 1990s resulted in declines of up to 90 per cent in marine iguana populations, 75 per cent in Galápagos penguins (Spheniscus mendiculus) and 50 per cent declines in sea lions (Zalophus californianus wollebacki) and flightless cormorants (Larrea and DiCarlo 2011). | Impacts | 67 - 68 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Wet soils and increased vegetation have reduced the temperature of soils, causing turtle nests to fail, and introduced fire ants (Solenopsis) have been seen to kill hatchlings in wet El Niño years (Trueman et al. 2011). Giant tortoises have also been observed falling down ravines or drowning in floods during extreme weather. Endemic land birds, too, appear to suffer in El Niño years – although breeding birds tend to respond positively to wet years, this appears to be offset by the impact of introduced diseases and parasites, with avian pox and the parasitic fly Philornis downsii being of particular concern (Dvorak et al. 2012; Trueman et al. 2011). Probably introduced in the 1890s, avian pox increased dangerously in seven species of finch between 2000 and 2009 (Zylberberg et al. 2012). | Impacts | 69 - 69 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Already under pressure from tourism development, population growth and the impacts of introduced species, the native wildlife and ecosystems of the Galápagos will be significantly affected by changes in the climate. The key factor looks likely to be how changes in El Niño and other cyclical events are manifest under global warming and how ocean currents and productivity respond. | Impacts | 69 - 69 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Recent climate change is having major impacts on the Cordillera Blanca. Since the 1930s, the area's glaciers have shrunk by 30 per cent (Schauwecker et al. 2014) and, in the 30 years since their first comprehensive inventory, 151 smaller glaciers of less than 1 square kilometre have disappeared (Portocarrero 2011). Observed WH_and_Tourism_23_may.indd 69 H_and_Tourism_23_may.indd 69 24/05/2016 05:26 4/05/2016 05:26<br>70 World Heritage and Tourism in a Changing Climate trends also include a rise in the elevation of glaciers and an increase in the number of glaciers due to the disintegration of larger ice bodies (Racoviteanu et al. 2008). Furthermore, studies of temperature changes in the Cordillera Blanca report an increase of 0.39ºC per decade between 1951 and 1999, with some slowdown in the rate of temperature increase in the more recent years (Schauwecker et al. 2014; Mark and Seltzer 2005). | Impacts | 71 - 72 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | There are several concerns associated with glacier retreat. One of them is its impacts on water availability – the ongoing retreat of the glaciers, coupled with increasing population, makes the Andean communities more and more vulnerable to declining water resources (Baraer et al. 2012). | Impacts | 72 - 72 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Huascarán National Park is also being affected by other threats, including overgrazing which leads to soil degradation (SERNANP 2013). The combination of these factors could lead to serious social conflicts in the area. Glacier retreat is also increasing the risk of natural disasters, including avalanches and glacier-lake outburst floods Atlantic Forest South-East Reserves, Brazil, 1999 (vii), (ix), (x) Once a lush forest covering about 134 million hectares, the Brazilian Atlantic Forest has now been reduced to less than 15 per cent of its original area and what remains is highly fragmented. The Atlantic Forest is a biodiversity hotspot, with hundreds of species found nowhere else on Earth, many of which are considered threatened or endangered, including the golden lion tamarin (Leontopithecus rosalia). Characterized by an environmental gradient from mountain slopes covered in dense forest to wetlands, as well as a variety of other habitats, the Atlantic Forest's proximity to the coast has been the main driver of its destruction. Urban development, land�use change, and illegal logging and occupation are key factors that threaten these ecosystems. | Impacts | 72 - 72 |

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| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Climate change, particularly in the form of sea-level rise and extreme weather, has more recently become a threat, with changing environmental conditions, landslides and floods following torrential rains, and droughts leading to habitat degradation and loss. Landslides have also caused loss of life in the encroaching urban dwellings all around the forest. Tourism, especially eco-tourism, has brought financial resources and awareness for conservation, and several non-governmental organizations have been working on conservation and adaptation initiatives, including restoration of degraded forests and other habitats to reduce the impacts of various threats. Improved connectivity between forest fragments will be a vital adaptive strategy as the climate continues to change. (GIZ; TNC; UNESCOc) WH_and_Tourism_23_may.indd 70 H_and_Tourism_23_may.indd 70 24/05/2016 05:26 4/05/2016 05:26<br>(GLOFs), with potentially disastrous impacts on nearby communities (Portocarrero 2011). | Impacts | 72 - 73 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | But even the disappearance of a glacier, despite being an irreversible loss, can create opportunities, and the community of Cátac has been working together with the Servicio de Áreas Naturales Protegidas por el Estado (SERNANP) and the Ministry of Tourism on the creation of a climate change trail (La ruta del cambio climático), which is designed to provide the visitors with scientific information on glacier retreat and help raise awareness of the effects of climate change. The trail and its associated infrastructure, including a lookout point from which the tourists can observe the current state of the dwindling glacier, were completed in 2014 (El Comercio 2014). | Impacts | 73 - 73 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Latin America 71– Rapa Nui National Park (Easter Island), Chile, 1995 (i), (iii), (v) Rapa Nui, or Easter Island, is famed for its iconic carved moai statues and ceremonial ahu platforms on which many of them stand, all dating back to around 1250–1500 AD. In the southeast Pacific Ocean more than 3 500 kilometres off the coast of Chile, Rapa Nui is the most remote inhabited island on Earth. With a resident population of approximately 5 000 people, the island's economy is dependent on tourism and some 60 000 people visit every year. During the summer months the island's population doubles, with an average of 5 000 tourists daily. The primary impacts of climate change on Rapa Nui are projected to be water shortages due to reduced summer rainfall, sea-level rise, coastal inundation and erosion. | Impacts | 73 - 73 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | The majority of the ahu and moai are located directly on the coast and significant coastal erosion impacts are already being recorded at several important archaeological sites. With climate change, the greater wave heights and increased energy of the waves hitting the ahu's vertical basalt slab walls, the ahu are expected to undergo worsening damage and the moai that sit on top of them could topple. Four of the sites most important for tourism – Tongariki, Hanga Roa, Tahai and Anakena – have recently been identified as among the most seriously threatened by wave damage. (UNESCO d; J. Downes, pers. comm.; Quilliam et al. 2014) WH_and_Tourism_23_may.indd 71 H_and_Tourism_23_may.indd 71 24/05/2016 05:26 4/05/2016 05:26<br>I Iulissat Icefjord, 400 kilometres north of the Arctic Circle in west Greenland, may be one of the few places in the world where climate change is helping to drive tourism. It is where the massive Sermeq Kujalleq or Jakobshavn Glacier meets the sea in the Disko Bay. The fjord, which is usually frozen over in the winter, offers summer visitors an incredible opportunity to see and hear the spectacular cracking and calving of ice into the ocean. The glacier has been studied by scientists for more than 150 years and has played a major part in the scientific understanding of glaciology (UNESCOa). One of the fastest-moving glaciers in the world, Jakobshavn has recently accelerated significantly and the ice sheet is thinning (NASA 2014). | Impacts | 73 - 74 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | A last-chance destination For such a remote place, Greenland and Ilulissat attract a significant number of tourists – some 60 000 a year – approximately half of them arriving on cruise ships (Stromberg 2011). The number of cruise ships travelling to Greenland increased from 13 in 2003 to 39 in 2008, and climate change impacts are being used to promote Ilulissat Icefjord (Greenland), Denmark Date of inscription: 2004 Criteria: (vii), (viii) Significance: geologic phenomenon that helps scientists understand the last ice age and climate change; wild and scenic combination of rock ice and sea; fast-moving glacier WH_and_Tourism_23_may.indd 72 H_and_Tourism_23_may.indd 72 24/05/2016 05:26 4/05/2016 05:26<br>the island as a destination to be seen before it disappears (Hall and Saarinen 2010). Greenland has taken full advantage of climate change promotional opportunities, as reflected in the government's tourism website, Greenland.com: "visiting the Ilulissat Icefjord is not only about seeing a large calving glacier or melting icebergs before it's too late. It is a unique opportunity to be active in the climate change conversation here at 'ground zero' and to let your experiences in Greenland inspire your life back home". | Impacts | 74 - 75 |

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| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | The recent dramatic increase in the rate of flow of Jakobshavn Glacier may have been caused by the loss of its floating ice tongue, the penetration of surface meltwater to the base of the glacier, the wider and deeper geology at the current terminus of the glacier, higher ocean temperatures, or a combination of all these (Joughin et al. 2014; Holland et al. 2008; Alley et al. 2005). Jakobshavn Glacier retreated 40 kilometres between 1850 and 2010, but the rate of retreat and thinning has increased markedly and it is now losing more mass than it is gaining each year (NASA 2015). Already a fast-moving glacier, Jakobshavn's speed reached a peak of 17 kilometres over the year in 2012, three times the annual rate of the 1990s (Joughin et al. 2014). | Impacts | 75 - 75 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Arctic archaeological sites are extremely important globally because so much organic material, such as wood, bone, animal skins and hair, is preserved in frozen ground as the process of decay has been halted. Warming conditions in the Arctic are now rapidly leading to the loss of many archaeological resources that are vital for understanding the everyday and spiritual lives of the first peoples to live in these often inhospitable lands. Thawing permafrost, loss of sea ice leading to coastal erosion, and increasing tundra fires are putting archaeological sites and historic monuments at risk throughout the Arctic. | Impacts | 76 - 76 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | WH_and_Tourism_23_may.indd 74 H_and_Tourism_23_may.indd 74 24/05/2016 05:26 4/05/2016 05:26 Europe 75– 10–20 per cent for each 1° C of warming (Hollesen et al. 2015, 2012). In addition, the metabolism of bacteria actively decomposing the organic deposits in the thawing permafrost layer generates heat, which in turn accelerates the thawing of the frozen ground (Hollesen et al. 2015). This positive feedback cycle can speed the deterioration of vital evidence of the early inhabitants of Greenland as well as increasing the release to the atmosphere of carbon stored in the frozen soil. | Impacts | 76 - 77 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | The warming of the Earth's atmosphere and oceans, the faster rate at which the Arctic is warming in comparison to the rest of the globe, and the impacts of this warming on the melt rate of Jakobshavn Glacier, are as stark a warning of the seriousness of climate change as it is possible to get. Greenland is ground zero for climate change threats to the world's ice sheets. Research shows that rates of global sea-level rise have approached 1 metre per century in association with previous warming periods in the geological past, and these rates could reoccur in the future. Climate models suggest that the Greenland ice sheet could melt during the next 1 000 years and that a threshold triggering many metres of sea-level rise from ice sheet melting could be passed this century (Overpeck et al. 2006). | Impacts | 77 - 77 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | WH_and_Tourism_23_may.indd 77 24/05/2016 06:52 78 World Heritage and Tourism in a Changing Climate Climate change will alter the environmental conditions at these monuments and their associated landscapes and the ability to manage consequent change in environmental processes will determine how much a changing climate threatens these places. In Orkney, sea-level rise, the increasing frequency of storms and accelerated coastal erosion present major threats (Dawson 2013; Historic Scotland 2013), whilst Stonehenge and Avebury may be sensitive to increasingly extreme weather, including storms and flooding (UNESCO 2014). | Impacts | 79 - 80 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Temperatures in the southeast of England are projected to rise by 1–8ºC by the 2080s, slightly Five-thousand-year-old Skara Brae is on the front-line of sea-level rise and at risk from coastal erosion. | Impacts | 80 - 80 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Sea-level rise, increased storm frequency and intensity, and coastal erosion are major threats to coastal heritage throughout the UK. Some 17 per cent of the UK's coast is eroding and storm damage is expected to increase (Masselink and Russell 2013). Scotland has northern Europe's longest coastline aside from Norway, and conservative estimates suggest that 12 per cent of it is eroding. Of 11 500 archaeological and historic sites surveyed between 1996 and 2011, nearly a third were assessed as needing some sort of action or protection (Dawson 2013). | Impacts | 81 - 81 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Thought of as remote today, Orkney was for centuries an important maritime centre for trade and cultural exchange going back to around 3000 BC (Gibson 2014). Because of the importance of the sea in Neolithic life in Orkney, many archaeological sites are on the coast, and at least half are under threat from coastal erosion (Gibson 2014). Skara Brae is the highest-profile site at risk of eventual loss from coastal erosion – it was discovered when a storm blew away sand and ripped turf from the site in 1850, uncovering parts of the ruins of what turned out to be the best-preserved Stone Age dwelling complex in Western Europe, complete with stone houses, stone furniture including seats and shelves, and archaeologically rich middens or waste heaps (Gibson 2014). A sea wall was first constructed to protect Skara Brae from erosion in 1925 and periodic improvements have been made ever since, but the coast is eroding at either end of the wall. | Impacts | 81 - 81 |

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| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Meanwhile, in southern England, the world’s most famous Stone Age monument is being managed to minimize the impacts of growing tourism and the site’s potential sensitivities to changes in the climate. The huge megaliths of bluestone and Wiltshire Sarsen, some weighing more than 40 tonnes, attract more than 1 million visitors a year. A recent climate vulnerability assessment carried out by UNESCO and Historic England identified a wide range of ways in which climate change could affect the site. Warmer winters are likely to bring higher populations of burrowing mammals including badgers, moles and rabbits, which may destabilize stonework and disturb buried archaeological deposits. Hotter drier summers could increase the number of visitors, and could change the plant species in the grassland that currently stabilizes the site’s chalk downlands, exacerbating soil erosion problems. | Impacts | 81 - 81 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Of most concern for Stonehenge are increasing rainfall amounts, more extreme rainfall events and worsening floods. Flash floods can result in damage through gullying and wetter conditions are also expected to increase the impact of visitors walking on the site. Thirty kilometres away, extreme rainfall recently led to the River Kennet overflowing its banks and causing floods at both Avebury and Silbury Hill (UNESCO 2014). | Impacts | 81 - 81 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Archives at risk In Scotland, although Skara Brae is safe for the moment, many other archaeological sites are at risk of destruction by the sea. The threatened sites contain archives of data that can help inform society about human adaptation to previous changes in climate. If no action is taken, however, these archives will be lost. | Impacts | 81 - 81 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Scotland’s Coastal Heritage at Risk Project (SCHARP) is adopting an innovative citizen�science approach to such sites, working with local communities who report new discoveries, update databases and get involved in practical projects, including excavations. | Impacts | 81 - 81 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | As successful as the protection of the area has been over the years, a number of problems remain for which solutions compatible with the sea’s protection goals need to be found. In the long term the most important of these may well be climate change and its expected impacts, a major concern in the Wadden Sea region with numerous studies and scientific papers dedicated to this subject. A number of key issues and potential climate change impacts have been identified, including direct effects of sea-level rise, disturbance of natural processes and loss of habitat for many species. | Impacts | 83 - 83 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | The morphodynamic development of the Wadden Sea is influenced by changing environmental conditions such as sea-level rise, as well as by human interference (Wang et al. 2012). Sea-level rise, with increased frequency of storm surges and higher inputs of energy, could lead to the dwindling of intertidal areas and increase the risk of coastal lands being flooded (Stevens and Associates 2006). Erosion of beaches, mudflats and salt marshes, and other coastal damage may increase due to accelerated sea-level rise (Fitzgerald et al. 2008). | Impacts | 83 - 83 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Due to its sediment-importing capacity, the system has been able to cope with rising waters for many centuries, but the accelerated rate of rise expected as a result of climate change WH_and_Tourism_23_may.indd 81 24/05/2016 05:48<br>82 World Heritage and Tourism in a Changing Climate may cause a loss of intertidal flats and salt marshes, leading to a decline in foraging and nesting possibilities for migratory and breeding birds (MELUR-SH 2015; Bairlein and Exo 2007; Brinkman et al. 2001). As a result of temperature rise, the plankton at the base of the food web may change, which could lead to changes higher up in the food web, including lower reproduction levels of fish populations and decreasing bird populations (NEAA 2014). In an ecosystem as complex as the Wadden Sea, the effects of climate change may also result in a cascade of yet unknown but wide-ranging changes. | Impacts | 83 - 84 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Shifts in ecosystem functioning will inevitably have consequences for sustainable use (Philippart and Epping 2009). This could include negative impacts on the provision of environmental services such as breeding, nursery and feeding grounds for commercially valuable fin and shell-fish (Stevens and Associates 2006). Freshwater availability on some of the Wadden Sea’s islands may also become an issue due to projected lower summer and higher winter precipitation (CWSS 2014b). | Impacts | 84 - 84 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | WH_and_Tourism_23_may.indd 82 24/05/2016 05:48<br>Europe 83– Recognizing that “climate change and enhanced sea-level rise may seriously impact structure, functions and characteristic biodiversity of the Wadden Sea ecosystem, as well as the safety of the inhabitants of the region”, in 2014 the Trilateral Wadden Sea Governmental Meeting adopted the Trilateral Climate Change Adaptation Strategy (CWSS 2014b), the overall goal of which is “to safeguard and promote the qualities and the integrity of the area as a natural and sustainable ecosystem whilst ensuring the safety of the inhabitants and visitors”. | Impacts | 84 - 85 |

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| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | This is expected to heavily influence the way in which the coastal defence administration will develop and effect measures in the future. As a contribution towards implementation of the strategy, WWF published a report with 13 case studies of international climate adaption efforts along “soft coasts” such as the Wadden Sea (Fröhlich and Rösner 2015). | Impacts | 85 - 85 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Although the effects of climate change may potentially have direct negative impacts on nature�based tourism in the Wadden Sea (Schasfoort and van Duinen 2014), some solutions can be developed to help minimize the impacts of the tourism sector itself and make it part of the solution. | Impacts | 85 - 85 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Catastrophic storm damage The worst flood in recent memory was in November 1966, when a massive storm system hit Italy, causing catastrophic damage to art and cultural heritage in Florence in the west and Venice in the east (Malguzzi et al. 2006). Venice and its inhabitants have for centuries struggled with the water and the maintenance of the lagoon, and have had to find ways to live with the high tides and storms. But the 1966 event provoked major discussion about how to protect Venice from future catastrophic floods. After decades of debate and planning, a series of 79 flood gates distributed across the three entrances that connect the Venetian Lagoon to the Adriatic Sea – the MOSE project – is due to be completed in 2017. These gates will rise whenever a tidal flood of 110 centimetres or more is predicted (Windsor 2015; Tosi et al. 2013), holding back the waters of the Adriatic until conditions improve. The total cost of these defences will be above EUR 5.4 billion (US$ 6.1 billion), and maybe more. | Impacts | 88 - 88 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Early design features beset by high tides Hundreds of buildings and monuments in Venice have already been damaged by rising seas. The city’s buildings were originally constructed by driving wooden posts deep into the mud of the lagoon, with dense, water-resistant Istrian stone foundations laid on these pilings and the fabric of the house built on top using brick, plaster and marble. A projecting stone moulding that separates the stone from the brick prevented waves from splashing upwards and wetting and Venice’s waters have risen by some 30 centimetres since the end of the 19th century. | Impacts | 88 - 88 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | WH_and_Tourism_23_may.indd 86 H_and_Tourism_23_may.indd 86 24/05/2016 05:26 4/05/2016 05:26 Europe 87– damaging the brickwork (Camuffo et al. 2014). But the water level is now often above the stone bases at high tide and the damp then rises by capillary action. Damage is caused by salts in the bricks or stone dissolving and then recrystallizing – San Polo Church, for example, has been severely affected (Camuffo 2001). The situation has been made worse by the dredging of deep-water channels for shipping, allowing more sea water to enter the lagoon and increasing the salinity of the water (Camuffo 2001; Penning-Rowsell 2000). | Impacts | 88 - 89 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Where the waters have risen above the stone foundations, damp is rising to higher levels where it decays the iron tie-rods that stabilize buildings and hold their walls together, deteriorating the marble and, in St. Mark’s Basilica, damaging the small tiles (tesserae) of the 1 000-year-old mosaics placed 6 metres above the floor (Cocks 2013). Statues and monuments, too, are being damaged; for example, the marble statues of the cenotaph built by the 18th century Venetian sculptor Antonio Canova in the Santa Maria Glorioso dei Frari Basilica, are rapidly deteriorating as a result of water entering the building and being drawn up into the marble by capillary action, eventually emerging on the surface of the statues, causing areas of flaking and blistering. | Impacts | 89 - 89 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Venice is now under assault from rapidly growing tourist numbers as well as worsening climate�driven water damage to the very buildings, and architectural and monumental heritage that draw visitors in the first place. Ironically, tourism is responsible for thousands of Venetian jobs and tens of millions of dollars in revenue to the city and its businesses, but the effects of climate must be addressed if the historic centre is to survive at all, and tourism must be better controlled if Venice is to remain a thriving and diverse community. | Impacts | 89 - 89 |
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| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Reefs at Risk Revisited. World Resources Institute, Washington, DC, USA. | Impacts | 90 - 90 |

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| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Kovats, R.S., Valentini, R., Bouwer, L.M., Georgopoulou, E., Jacob, D., Martin, E., Rounsevell, M. and Soussana, J.-F. 2014. Europe. In: Barros, V.R., Field, C.B., Dokken, D.J., Mastrandrea, M.D., Mach, K.J., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., Girma, B., Kissel, E.S., Levy, A.N., MacCracken, S., Mastrandrea, P.R. and White, L.L. (eds) Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the IPCC. Cambridge University Press, Cambridge, UK and New York, NY, USA. | Impacts | 105 - 105 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Masselink, G. and Russell, P. 2013. Impacts of climate change on coastal erosion. MCCIP Science Review 71–86. doi:10.14465/2013.arc09.071-086. | Impacts | 105 - 105 |
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| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Schasfoort, F. and van Duinen, R., 2014. Tourist Valuation of Climate Change Impacts on the Dutch Wadden Sea: A Travel Cost Method and Choice Experiment. Report to the European Commission. | Impacts | 106 - 106 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | UKDEFRA. 2012. UK Climate Change Risk Assessment: Government Report. UK Department for Environment, Food and Rural Affairs. Her Majesty's Stationary Office, London, UK. | Impacts | 106 - 106 |
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| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Werritty, A., and D. Sugden, 2012. Climate change and Scotland: recent trends and impacts. Earth and Environmental Science Transactions of the Royal Society of Edinburgh 103: 133–147. | Impacts | 106 - 106 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | World Heritage and Tourism in a Changing Climate, through 12 fully referenced case studies and 18 shorter views of cultural and natural World Heritage sites, shows how climate-driven changes, now and in the future, threaten their outstanding universal value and integrity, as well as the economies and communities that depend on their tourist appeal. The case studies were chosen for their geographic representation, diversity of types of natural and cultural heritage and importance for tourism. Most importantly, they provide examples of a wide range of climate impacts, supported by robust scientific evidence. | Impacts | 108 - 108 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Drawing together common themes in the relationship between World Heritage, climate change and tourism, World Heritage and Tourism in a Changing Climate presents a series of stakeholder recommendations for action. These aim to help minimize the impacts of climate change on World Heritage properties and promote a more sustainable development of tourism. | Impacts | 108 - 108 |

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| UNESCO | Adapting to Change (2011) | The dynamic history of forests Forests often seem eternal, stable representations of mature and stately ecosystems. But the venerable concept of relatively stable 'climax' forest ecosystems that are hundreds, or even thousands, of years old has now been replaced by the recognition that forests are in a constant state of change, requiring more adaptive forms of management (Hollings, 1978). Resource managers now need to consider the dynamic forces of fires, storms, droughts, climate change, and other natural factors with the usual human impacts such as logging, introduction of non-native species, building of roads, planting of vast plantations of genetically identical trees, and so forth. | Adapt-MitigImpacts | 11 - 11 |
| UNESCO | Adapting to Change (2011) | Isolating a forest by excessive land use changes around it will have significant repercussions on its ability to maintain its composite biodiversity and to provide ecosystem services, rendering it more susceptible to disturbance. In this regard, no forest is an island. Ironically, in strictly legal terms, World Heritage forests tend to be managed as if there were islands. They must be designated with bound�aries that indicate which government agency has responsi�bility for maintaining its World Heritage values. As a result, though a forest is extensively connected to the lands around it, management is often designed as though they were closed systems and it is often forced to function with little interaction or mandate to engage with landscape level stakeholders who may have an influence on systems, which in turn may affect World Heritage forests. The long�term well being of World Heritage forests is therefore at risk from both ecological and institutional isolation. | Adapt-MitigImpacts | 12 - 12 |
| UNESCO | Adapting to Change (2011) | The evolutionary forces of isolation may be disrupted, fires may find it easier to spread, and disease may no longer be impeded by buffer zones. These risks will need to be incor�porated, as connectivity becomes a more central concern in forest management (Ewers and Kapos, this volume). | Adapt-MitigImpacts | 12 - 12 |
| UNESCO | Adapting to Change (2011) | 14 11 Adapting to Change – The State of Conservation of World Heritage Forests in 2011<br>Reducing external impacts on World Heritage forests Global demand for forest products continues to expand, though the rate of increase is surprisingly modest, increasing by only 0.4 per cent per year since 1980. But over the same time, paper consumption increased at an annual rate of 3.2 per cent, and sawn timber and wood panels increased by 0.8 per cent per year (Ajani, 2011). | Adapt-MitigImpacts | 13 - 14 |
| UNESCO | Adapting to Change (2011) | Adapting to climate change Once monitoring has provided information on changes taking place, the next and more complex challenge lies in implementing effective adaptation measures. All ecosys�tems change through time. The challenge facing us today is to understand where changes will threaten the Outstanding Universal Values that qualify a site as World Heritage, and understand if and how we can do some�thing about it, and when we cannot, then act on that information. Adaptive strategies include land management (i.e. establishing ecological corridors to allow the migra�tion of plants and animals, and buffers to increase the resilience of sites), on-site management (i.e. encouraging or discouraging vegetative patterns), and management of human impacts (i.e. fire risk). It is likely that a systematic and full response to climate change for all World Heritage forest sites will be restricted by financial capacity. To prior�itize action, the sites that are at highest risk, the drivers of that risk, and those with potential for greatest adaptive opportunities, all need to be identified. | Adapt-MitigImpacts | 22 - 22 |
| UNESCO | Adapting to Change (2011) | Therefore, there will always be uncertainty about a predicted future. That uncertainty requires adaptive management (i.e. taking action on the ground, measuring effects, and changing management as necessary). It also requires being routinely aware of the growth in model effectiveness, so that management is based on reasonable climate scenarios. | Adapt-MitigImpacts | 23 - 23 |
| UNESCO | Adapting to Change (2011) | The most significant decision to be made regarding climate change adaptation and ecological monitoring is the audience for the results, and the actions one wishes that audience to take. A proactive climate-change response plan for a World Heritage forest should include stakeholder definition (i.e. who are the people who care about and have the ability to act upon impacts of climate change at the site?). A monitoring programme, including both climatic and ecological variables will inform those stakeholders and guide their actions. An actively engaged site manager will be able to provide data and information about his/her site, and the ways climate-related changes are affecting that site, or might affect it in the future. A stakeholder group will be able to develop and assess large scale adaptive strategies such as the purchase or manage�ment of adjacent lands, the formulation of land use poli�cies designed to encourage certain behaviours among land owners, or management of human impacts (i.e. better fire control capacity). | Adapt-MitigImpacts | 25 - 25 |
| UNESCO | Adapting to Change (2011) | A serious constraint faced by all World Heritage forest site managers is resource limitation. Each site has a rela�tively limited budget that can be invested in manage�ment, M&A, and all the other demands placed on the site's budget. Investing in climatic and/or ecological monitoring represents one more demand on limited resources; setting priorities among those competing demands is a central function of management. There are at least two resources that would help an individual site manager evaluate climate change related risks compared to competing priorities: • Global models that evaluate relative climate change risk at World Heritage sites (i.e. Perry, 2011, Epple et al., 2010) identify sites perceived to be most at risk, and identify perceived causal factors (i.e. what makes one site more at risk than another). Sites generally perceived to be at higher risk will find monitoring an important investment. Variables perceived to drive vulnerability at a given site will often be useful components of a moni�toring programme. | Adapt-MitigImpacts | 25 - 25 |

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| UNESCO | Adapting to Change (2011) | Summary Some World Heritage forest sites are at much higher risk of climate related changes than others. Recent attempts to assess relative climate change risk among World Heritage sites assist individual site managers in under�standing the magnitude of the risks they face, as well as the specific on-site variables most strongly driving such risk and therefore, most likely to change. Carefully designed and implemented ecological and climatic moni�toring programmes that actively engage a strong stake�holder base will be most effective in detecting and responding to climate induced changes. A proactive strategy will ensure the best decisions. Elements of such a strategy should include: 1) developing a World Heritage forest adaptation toolkit, 2) engaging the World Heritage forest community (i.e. managers and staff of the 104 designated forest sites) in an active discussion of antici�pated, climate induced changes, and 3) pairing sites to share analytical ideas and approaches. Actions such as those will increase the probability that climate change impacts are detected early and that proactive, adaptive strategies are identified and considered in a timely way.<br><br>3. Conservation Science Group, Department of Zoology, University of Cambridge, Downing Street, Cambridge CB2 3EJ, UK. | Adapt-MitigImpacts | 25 - 25 |
| UNESCO | Adapting to Change (2011) | WH WH WH One set of these relates to corridors of forest, such as riparian forests that are often preserved along river margins, and may connect a World Heritage forest to other forest areas. Corridors are known to promote the dispersal of species between habitat patches, thereby reducing biodiversity loss within them (Damschen et al., 2006). The likely efficacy of a corridor can be assessed using four criteria: (a) wide corridors are preferable to narrow corridors, as many species avoid forest edges and are therefore unlikely to move through a narrow strip of forest (Ewers and Didham, 2007); (b) shorter corridors are more likely to allow successful dispersal between patches than long corridors; (c) similarly, a corridor should ideally be continuously forested with no breaks, such as might be created by roads crossing the corridor (this is not to say that a 'broken' corridor will not function; as long as a species will cross small gaps then the individual patches of forest along that corridor can act as 'stepping stones', facilitating the movement of a species from one location to another); (d) finally, the size of the forest patch at the other end of the corridor is a strong determinant of the size of populations inhabiting that patch and therefore the likelihood of individuals leaving the patch to disperse along the corridor (Hanski, 1998). Corridors that connect a World Heritage forest to a large forest patch are likely to have a larger beneficial effect for the World Heritage forest than those connecting to a small forest patch.<br><br>http://cmsdata.iucn.org/downloads/forests_1.pdf Adapting to changes 31 2 | Adapt-MitigImpacts | 27 - 28 |
| UNESCO | Adapting to Change (2011) | Introduction A shift from the traditional exclusionary conservation paradigm towards a more integrative landscape approach can be seen in the management philosophies of protected areas (PAs) (Phillips, 2003). This derives partly from a better scientific understanding of how humans have been shaping ecosystems and landscapes, increasing recognition of local and indigenous communities as well as uncertainties regarding the potential impacts of global climate change (Sayer and Maginnis, 2005). In addition, the frequent shortcomings in funding for PA manage�ment is an incentive for exploring new possibilities to monetize ecosystem services that are delivered by PAs (de la Harpe et al., 2004). In this regard, payment schemes for carbon sequestration services in the context of Reducing Emissions from Deforestation and Forest Degradation in Developing Countries (REDD+), as currently negotiated under the United Nations Framework Convention on Climate Change (UNFCCC), might play a considerable role as an additional source of long-term funding for forest PAs in the future (Dudley, 2008; Harris et al., 2008). | Adapt-MitigImpacts | 29 - 30 |
| UNESCO | Adapting to Change (2011) | Benefits and risks of REDD+ for biodiversity Additional benefits for biodiversity that can be derived from REDD+ include the conservation of forest biodiversity beyond the mere protection of forest cover, the establish�ment of corridors between PAs (see Chapter 4 on connec�tivity) (Wendland et al., 2009), the reduction of forest fire incidents (Stickler et al., 2009) and securing the sustain�able delivery of forest ecosystem services (UN-REDD, 2009). Furthermore, there are opportunities for enhancing biodiversity monitoring in and outside PAs. | Adapt-MitigImpacts | 30 - 30 |
| UNESCO | Adapting to Change (2011) | Furthermore, there is the risk of inter-ecosystem leakage since forest conservation under REDD+ can trigger a shift of land use conversion pressures to non-forest ecosystems with high biodiversity, such as peatlands or grasslands (Klink and Machado, 2005; Miles and Kapos, 2008; Paoli et al., 2010). PAs may also be threatened by leakage if REDD+ activities outside the PAs lead to an increase in deforestation pressure within the PAs. | Adapt-MitigImpacts | 30 - 30 |
| UNESCO | Adapting to Change (2011) | Notwithstanding these potential risks, REDD+ activities – if properly designed – can contribute to the long-term funding of PAs and to the conservation of biodiversity and ecosystem services in PAs within a landscape scale approach. World Heritage forest sites have Outstanding Universal Value (OUV) in terms of forest biodiversity and delivery of important ecosystem services (Ripley, 2007) and are therefore sites with high potential for achieving syner�gies between climate and biodiversity objectives under REDD+. The synergies between REDD+ and the long-term conservation of World Heritage forest sites are starting to be widely recognized, as demonstrated by the increasing 32 2 Adapting to Change – The State of Conservation of World Heritage Forests in 2011 REDD+ as a Contribution to Conservation and Connectivity of World Heritage Forest Sites by Steffen Entenmann and Christine B. Schmitt Institute for Landscape Management, University of Freiburg, Germany 1 1. University of Freiburg, Tennenbacher Strasse 4, D-79106 Freiburg. | Adapt-MitigImpacts | 30 - 30 |
| UNESCO | Adapting to Change (2011) | An important conceptual framework applied by many certification schemes for assessing forest biodiversity is the High Conservation Value (HCV) concept developed by the Forest Stewardship Council (FSC). This concept recognizes six types of HCV forests and provides guidelines for moni�toring the ecological conditions and changes in forests. It also recognizes whether the project area provides habitats to species listed on the IUCN Red List of Threatened Species, as well as important ecosystem services such as the provision and storage of water and the protection of soil against erosion. | Adapt-MitigImpacts | 31 - 31 |

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| UNESCO | Adapting to Change (2011) | REDD+ activities can be an important contribution to reduce GHG emissions and improve conservation effec�tiveness in PAs of all IUCN management categories9. In PAs under IUCN categories I-IV, REDD+ measures can help in reducing illegal logging and increasing the conservation effectiveness, while in PAs under IUCN categories V-VI, REDD+ can help in reducing GHG emissions from legal forest management activities i.e. through sustainable forest management and the enhancement of carbon stocks; however, the biodiversity impacts of these activi�ties need to be carefully considered.<br><br>36 2 Adapting to Change – The State of Conservation of World Heritage Forests in 2011 9. For an explanation: http://www.unep-wcmc.org/protected_areas/categories/index.html | Adapt-MitigImpacts | 34 - 34 |
| UNESCO | Adapting to Change (2011) | It is fair to assume that conservation or the creation of forest corridors, including secondary forests or structurally rich plantations adjacent to World Heritage forest sites, usually has positive impacts on ecological connectivity. | Adapt-MitigImpacts | 34 - 35 |
| UNESCO | Adapting to Change (2011) | Proximity to World Heritage forest sites could be taken into account when evaluating the effects on biodiversity of a REDD+ project as World Heritage forest sites per se have OUV and contain unique species and habitats. At least for the voluntary carbon market, where some buyers of carbon certificates are willing to pay a premium for carbon credits generated in projects with certified positive impacts of biodiversity, this might add value to the conservation effort and increase the price of the carbon credits. In order to keep track of the impacts on biodiversity of REDD+ in the World Heritage forest sites, objectives for biodiversity monitoring must be defined, and monitoring systems need to be established. This is automatically given if the REDD+ project takes place within the World Heritage forest site, but could also be required if it is located outside the World Heritage site, for example, the CCBA standard requires the assessment of off-site biodiversity impacts. | Adapt-MitigImpacts | 35 - 35 |
| UNESCO | Adapting to Change (2011) | Despite a reported overall decrease in threats to World Heritage forests in recent years, the 2001–2006 Threat Intensity Coefficients for a number of tropical sites demon�strate the potential for improved management and enforcement to reduce pressures from agricultural encroachment and deforestation (Patry and Ripley, 2007; Patry, 2007b). For World Heritage forests facing consider�able encroachment, engagement with REDD+ may depend on their ability to document these threats and the resulting/potential carbon losses. | Adapt-MitigImpacts | 37 - 37 |
| UNESCO | Adapting to Change (2011) | • The World Heritage Committee might engage with the CBD effort to maximize the biodiversity conservation outcomes of REDD+ interventions. It might contribute to the development of indicators for measuring the biodi�versity impacts of REDD+ actions. The CBD is also lobbying for a REDD+ mechanism that also prioritizes co-benefits, and the Committee might consider whether to take a similar advocacy position. | Adapt-MitigImpacts | 42 - 42 |
| UNESCO | Adapting to Change (2011) | Next, we examined the certification assessment reports for each of these nine operations. Among other things, the assessment report identifies areas of non-conformance – areas where the candidate forestry operation is not in compliance with FSC standards. When this happens, oper�ations are issued a Corrective Action Request, or 'CAR', that clearly specifies the action that must be taken to come into compliance with the standard. If the non�conformance is minor, the FSC certificate is awarded and the operation is given time – typically one year – to imple�ment the CAR. If the infraction is severe, a major CAR is issued and the FSC certificate is not awarded until CAR implementation is verified.6 Though not a perfect proxy for impact, we believe that the CARs issued to an operation do provide valuable insights into the areas where certification has resulted in forest management improvements. Because we were specifically interested in the changes that RA/FSC-certified companies made that might affect the adjacent World Heritage sites, we looked for CARs that required operations to take corrective actions that would: • Improve High Conservation Value Forest (HCVF) assess�ment • Conserve HCVFs • Protect rare, threatened or endangered species or their habitats • Limit the movement of invasive species • Prevent or contain forest fires • Improve worker wages or working conditions • Enhance the viability of local communities In the sections that follow, we identify those World Heritage sites with adjacent RA/FSC-certified forestry oper�ations, outline the current threats that these sites face, and describe the ways that their certified neighbours might be contributing to their effectiveness and integrity. | Adapt-MitigImpacts | 45 - 45 |
| UNESCO | Adapting to Change (2011) | Tembec's CARs required the assessment and management of HCVF areas, and the creation of larger 'protected reserve' areas. Practices within riparian zones were also addressed, with one CAR requiring the creation of a 7- metre machine-free zone along all water bodies, except where required for stream crossings. Tembec was also required to mitigate the damages associated with mineral exploration roads in areas designated as HCVFs. | Adapt-MitigImpacts | 46 - 46 |
| UNESCO | Adapting to Change (2011) | Landscape Labelling – the explicit association of the label with a sustainably managed landscape – could allow local stakeholders to capitalize on World Heritage status. Thus landscapes that encompass World Heritage forests might be managed in such a way as to minimize impacts on the protected forests by, for example, encroachment, pollu�tion, invasive species, and so on. Remnant forest patches or other natural habitats might also be actively maintained within the landscape, thereby improving the quality of the landscape matrix for forest species, and thus extending the conservation benefits of the World Heritage forests into the surrounding landscape. Recognizing such management activities through the designation of a wider Landscape Label might provide one pathway by which these activities can continue to be incentivized and rewarded. | Adapt-MitigImpacts | 54 - 54 |

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| UNESCO | Adapting to Change (2011) | At the heart of the Strategic Plan are twenty ambitious but realistic targets collectively known as the Aichi Biodiversity Targets. These targets must be met over the next decade if the plan is to be realized. The implementation of the Plan coincides with the International Decade of Biodiversity 2011–2020 announced by the UN General Assembly in December 2010. There are four targets that are directly relevant to forests and protected areas, including World Heritage sites. These 2020 targets include: • to at least halve, and where feasible bring close to zero, the rate of loss of all natural habitats, including forests, and to significantly reduce degradation and fragmenta�tion (Target 5); • to manage areas under agriculture, aquaculture and sustainably managed forests (Target 7); • to conserve at least 17 per cent of terrestrial and inland water and 10 per cent of coastal and marine areas (Target 11); and 60 3 Adapting to Change – The State of Conservation of World Heritage Forests in 2011 Forests and Protected Areas: Outcomes of the Tenth Meeting of the Conference of the Parties to the Convention on Biological Diversity by Johannes Stahl, Tim Christophersen and Jason Spensley Secretariat of the Convention on Biological Diversity, Montreal, Canada<br>• to enhance the resilience and the contribution of biodi�versity to carbon stocks through conservation and restoration, including restoration of at least 15 per cent of degraded ecosystems, thereby contributing to climate change mitigation and adaptation, and to combating desertification (Target 15). | Adapt-MitigImpacts | 57 - 58 |
| UNESCO | Adapting to Change (2011) | • Finally, decision X/33 on biodiversity and climate change contains several paragraphs related to reducing emis�sions from deforestation and forest degradation in developing countries (REDD-plus). The decision invites 62 3 Adapting to Change – The State of Conservation of World Heritage Forests in 2011 Not for food: Control of bushmeat harvesting is a key part of the CBD forest agenda. © CBD Secretariat 1. The full text of the Strategic Plan, including all the Aichi Biodiversity Targets, is available at: http://www.cbd.int/sp 2. The full texts of these decisions are available at: http://www.cbd.int/deci�sions<br>Parties and other governments to enhance the benefits for and avoid negative impacts on biodiversity from REDD-plus, and other sustainable land management and biodiversity conservation and sustainable use activities. It requests the Executive Secretary to provide advice on relevant REDD-plus safeguards for biodiversity, based on effective consultation with Parties and their views, and with the participation of indigenous and local communi�ties. It also requests the Executive Secretary to identify possible indicators that assess the contribution of REDD�plus towards achieving the objectives of the CBD, and to assess potential mechanisms that monitor the impacts of REDD-plus on biodiversity. | Adapt-MitigImpacts | 59 - 60 |
| UNESCO | Adapting to Change (2011) | CBD LifeWeb Initiative The CBD LifeWeb Initiative facilitates financing for protected areas to conserve biodiversity, address climate change and secure livelihoods. Managed by the CBD Secretariat, LifeWeb was invited by the Conference of the Parties to the CBD in its decision IX/18(11–12), and was reinforced by decision X/31 in 2010. It provides value�added by: (i) serving as an electronic clearing house of funding priorities; (ii) supporting Parties to hold financing roundtable meetings to strengthen international coopera�tion based on national priorities for protected area systems; and (iii) recognizing financing for priorities conveyed through CBD LifeWeb. Since 2009, sixteen donor partners have provided over US$120 million in funding support for projects profiled through this clearing house. Much of this support has been for the conserva�tion and restoration of forest areas. Over thirty-five coun�tries are currently profiling further priorities, and partner�ships are being sought with support of CBD LifeWeb for an additional US$720 million. World Heritage Sites are of special relevance to CBD LifeWeb, particularly given their unique visibility and the need for good examples of ecosystem goods and services that can be derived from the effective management of protected areas.3 REDD-plus consultations In collaboration with partners, the Secretariat organizes a series of regional consultation and capacity-building workshops on REDD-plus, including on relevant biodiver�sity safeguards. The workshops aim to consult effectively with Parties on biodiversity aspects of REDD-plus. They develop advice on REDD-plus and relevant safeguards, on possible indicators to assess the contribution of REDD-plus to achieving the objectives of the CBD, and on potential mechanisms to monitor the impacts of REDD-plus on biodiversity. The workshops also contribute to capacity�building on REDD-plus. The results are intended to support both the CBD and the United Nations Framework Convention on Climate Change discussions on safeguards, as well as on the monitoring of biodiversity in the context of the forest related targets of the Strategic Plan. | Adapt-MitigImpacts | 61 - 61 |
| UNESCO | Adapting to Change (2011) | 66 3 Adapting to Change – The State of Conservation of World Heritage Forests in 2011 Category of forest user Cash income Non-cash income Total Forest income as a percentage of total income Wealthy and average men 42 58 100 Of which forest 7 31 38 Wealthy and average women 36 64 100 Of which forest 10 34 44 Poor and very poor men 38 62 100 Of which forest 9 36 45 Poor and very poor women 32 68 100 Of which forest 12 38 50 Average contribution of cash and non�cash income to total income 37 63 100 Average contribution of forest income to total income 9 35 44 Table 1. Forest use in the village of Tenkodogo, Burkina Faso (per cent)<br>The importance of World Heritage forests World Heritage forests could play a tremendous role in promoting the essential values of forests. With 104 protected forests now recognized as World Heritage prop�erties, the network of World Heritage forests brings together the world's most outstanding forests, many of which provide the greatest value in terms of beauty, but also biodiversity, carbon storage, erosion prevention, and of course social and cultural values, which after all lie at the core of the concept of the World Heritage Convention. | Adapt-MitigImpacts | 63 - 64 |

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| UNESCO | Adapting to Change (2011) | The vision of human populations acting as key players in biodiversity conservation and sustainable use has been embedded in UNESCO's Man and the Biosphere (MAB) Programme since its launch in 1971. The issue of forests, infused with the notion of their ecological, economic and cultural values, has been addressed by the MAB Programme since its earliest days. From scientific projects, addressing the issues of ecological effects of increasing human activities on tropical and sub-tropical forest eco�systems, and ecological effects of different land uses and management practices on temperate and Mediterranean forest landscapes, the MAB Programme has gradually shifted its focus towards exploring how the improved protection and management of forested landscapes in and around specific sites, or biosphere reserves, could contribute to biodiversity conservation while improving social, economic and cultural well-being of resident human communities. | Adapt-MitigImpacts | 65 - 65 |
| UNESCO | Adapting to Change (2011) | It is interesting to note that forty out of one hundred and three World Heritage forests 2, thus more than one-third, constitute the legally protected core area of forest biosphere reserves, with eleven located in post-Seville sites (Table 1). In this context, and bearing in mind the alarming rate of forest destruction and degradation worldwide, there is a need to explore and document ways and means in which the dual World Heritage–Biosphere Reserve designation can increase the effectiveness of long-term conservation of World Heritage forests as well as fulfilling the overall conservation and development functions of biosphere reserves. | Adapt-MitigImpacts | 65 - 65 |
| UNESCO | Adapting to Change (2011) | • Bia Biosphere Reserve, Ghana Ghana submitted a funding request to the UNESCO Participation Programme during the 2010–2011 funding period to carry out a climate change impact assessment study on the Bia Biosphere Reserve. The aim of this study is to obtain scientific knowledge on the cause and effect relationship of climate change on the biosphere 70 3 Adapting to Change – The State of Conservation of World Heritage Forests in 2011<br>reserve in order to develop sound mitigation and adap�tation measures for the ecosystem. Subsequently, these mitigation and adaptation options will be integrated into the biosphere reserve's current management plans. | Adapt-MitigImpacts | 67 - 68 |
| UNESCO | Adapting to Change (2011) | 82 4 Adapting to Change – The State of Conservation of World Heritage Forests in 2011 Figure 2. A map of cumulative forest fires in the region between 2005 and 2009<br>Case Studies – On Connectivity 83 4 Figure 3. Climate change and biodiversity hotspots in Mesoamerica Source: Anderson, E.R., Cherrington, E.A., Flores, A.I., Perez, J.B., Carrillo R., and E. Sempris. (2008) Potential impacts of climate change on biodiversity in Central America, Mexico and the Dominican Republic. CATHALAC/USAID. Panama City, Panama, p.105.<br>Payment for Ecosystem Services The Payment for Environmental (ecosystem) Services (PES) is a promising tool for forest conservation. Two decades ago Costa Rica developed an innovative approach by establishing a fuel tax of 3.5 per cent that goes into paying forest owners a fee for the conservation of standing forests, regeneration areas and forest planta�tions. Four environmental services were recognized in the Biodiversity Law of 1996: biodiversity, water, carbon and landscape. This has allowed the country to actually double its forest cover over the last two decades, having now over 50 per cent of the country under forest, significantly contributing to re-establishing or maintaining ecological connectivity between protected area nodes. | Adapt-MitigImpacts | 78 - 80 |
| UNESCO | Adapting to Change (2011) | Limitations of established partnerships In practice, all these partnerships have limitations to the mobilization of resources capable of supporting the efforts necessary to apply the principles of sustainable develop�ment at a larger scale that encompasses the entire DFR landscape. The low participation and awareness of local communities in terms of the World Heritage forest concept, and the absence of information on the Dja Forum, which was implemented with the help of IUCN�Central Africa (BRAC) in the 1990s, have contributed to these shortcomings. The impact of these processes on community dialogue established by the 'Model Forest Partnership' is thus still limited. In particular, the issues of biodiversity conservation have yet to be fully appreciated by local and indigenous populations. Nevertheless, they are well aware of the current threat to a number of animal and plant species, for example, the overexploitation of Moabi tree (Baillonnella Toxisperma) for economic reasons. | Adapt-MitigImpacts | 84 - 84 |
| UNESCO | Adapting to Change (2011) | Another challenge is the absence of an environmental education curriculum. The impact of the 'Model Forest Partnership' is also limited by the fact that stakeholders do not have the necessary jurisdiction or mandate that would allow them to apply their ideas directly in the field, and which would allow them the opportunity to engage in biodiversity conservation. The notable lack of dialogue among certain local stakeholders is a direct consequence of insufficient consultation and inadequate institutional�ization of a co-management system. Every one of the stakeholders has their own management plan for bio�diversity in the same area. This is the case of Geovic, a mining company exploiting cobalt and nickel ores close to the reserve. | Adapt-MitigImpacts | 84 - 84 |
| UNESCO | Adapting to Change (2011) | Citing the term employed by Klein in 1991 (cited by Bourque, 2008), a Model Forest partnership built around these stakeholders is a form of new social contract estab�lished at the local level. However, there is an urgent need to implement and reinforce the institutional bodies outlined in the Decree No. 1052/MINFOF 17 December 2007 that approved and executed the development plan for the DFR so as to ensure a stronger participation of the local population, particularly the Bakas whose survival depends directly on the forest. The Bakas fully understand the biology of animals, their reproductive cycle, their feeding habits and their migratory movements across the landscape, and are thus one of the key partners for the sustainable management of the entire DFR. The FOMOD incorporates their thoughts and positions on such current issues as forestry governance, the REDD, and anthro�pogenic climate change. As regards local economic issues, FOMOD's partners participate in discussions on the mitiga�tion of negative impacts as a result of forest exploitation and the mining of cobalt, nickel and iron. Furthermore, stimulating the local economy remains one of FOMOD's priorities so as to find a solution to the endemic poverty visible around the protected areas (Dja Faunal Reserve and Nki National Park). | Adapt-MitigImpacts | 85 - 85 |

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| UNESCO | Adapting to Change (2011) | 90 4 Adapting to Change – The State of Conservation of World Heritage Forests in 2011<br>Introduction Latin America is covered by 22 per cent of the world's forest area. However, the condition of these forests is rapidly changing. Between 1990 and 2005, it experienced a 7 per cent decrease in area (64 million ha) principally as a consequence of the expansion of large-scale agriculture and cattle farming (FAO, 2009). Despite a significant increase in protected areas between 1990 and 2007 in the region, from 213 to 451 million ha, it is unlikely – espe�cially in South America – that the rate of deforestation will decrease (FAO, 2009). Add to that the change dynamic due to agricultural activities, tropical forests – in particular tropical dry forests – are at risk from the development of road infrastructure and the effects of climate change. | Adapt-MitigImpacts | 86 - 87 |
| UNESCO | Adapting to Change (2011) | During the glacial and interglacial periods, this forest advanced and retreated in successive episodes, serving as an ample shock-absorber between the dry ecosystems to the south and the humid ecosystems to the north (Pennington et al., 2004). Taking into account current characteristics such as area, state of conservation and connectivity with other ecoregions, including water basins, it plays a key role in mitigating the negative effects of climate change on the continent. | Adapt-MitigImpacts | 87 - 87 |
| UNESCO | Adapting to Change (2011) | 3) Based on information obtained from desktop study of WH nomination files and the WCMC protected areas database. Great variation in availability and quality of data implies that the figures are indicative only and will be permanently subject to refinement. The authors welcome any information leading to improvement of the figures.<br>Annexes 101 4) 0 = Minimum threat intensity; 100 = Maximum threat intensity; for further explanation see "A Selection of WH Forest Indicators" (this volume); for graphs on each site see Annex III<br>Ecological Zone1 102 Adapting to Change – The State of Conservation of World Heritage Forests in 2011 Annex II: World Heritage Forests - Inscription and Geographical Characteristics 1) BC = Boreal coniferous forest; BM = Boreal mountain system; TempC = Temperate continental forest; TempM = Temperate mountain system; TempO = Temperate oceanic forest; SubD = Subtropical Dry Forest; SubD = Subtropical dry forest; SubH = Subtropical Humid Forest; SubM = Subtropical Mountain System; TrD = Tropical dry forest; TrM = Tropical moist deciduous forest; TrMS = Tropical mountain system; TrR = Tropical rainforest 2) A = Afrotropical; Au = Australian; I = Indomalayan; N = Neotropical; Ne = Nearctic; O = Oceanic; PE = Palaearctic East; PW = Palaearctic West<br>Annexes 103 3) Further information on IUCN categories available online: http://www.iucn.org/about/work/programmes/pa/pa_products/wcpa_categories/<br>104 Adapting to Change – The State of Conservation of World Heritage Forests in 2011 Annex II: World Heritage Forests - Inscription and Geographical Characteristics 1) BC = Boreal coniferous forest; BM = Boreal mountain system; TempC = Temperate continental forest; TempM = Temperate mountain system; TempO = Temperate oceanic forest; SubD = Subtropical Dry Forest; SubD = Subtropical dry forest; SubH = Subtropical Humid Forest; SubM = Subtropical Mountain System; TrD = Tropical dry forest; TrM = Tropical moist deciduous forest; TrMS = Tropical mountain system; TrR = Tropical rainforest 2) A = Afrotropical; Au = Australian; I = Indomalayan; N = Neotropical; Ne = Nearctic; O = Oceanic; PE = Palaearctic East; PW = Palaearctic West<br>Annexes 105 3) Further information on IUCN categories available online: http://www.iucn.org/about/work/programmes/pa/pa_products/wcpa_categories/<br>UNESCO Inscription Criteria: Cultural i. to represent a masterpiece of human creative genius; ii. to exhibit an important interchange of human values, over a span of time or within a cultural area of the world, on developments in architecture or technology, monumental arts, town-planning or landscape design; iii. to bear a unique or at least exceptional testimony to a cultural tradition or to a civilization which is living or which has disappeared; iv. to be an outstanding example of a type of building, architectural or technological ensemble or landscape which illustrates (a) significant stage(s) in human history; v. to be an outstanding example of a traditional human settlement, land-use, or sea-use which is representa�tive of a culture (or cultures), or human interaction with the environment especially when it has become vulnerable under the impact of irreversible change; vi. to be directly or tangibly associated with events or living traditions, with ideas, or with beliefs, with artistic and literary works of outstanding universal significance. (The Committee considers that this crite�rion should preferably be used in conjunction with other criteria); Natural vii. to contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance; viii. to be outstanding examples representing major stages of earth's history, including the record of life, signifi�cant on-going geological processes in the develop�ment of landforms, or significant geomorphic or phys�iographic features; ix. to be outstanding examples representing significant on-going ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals; x. to contain the most important and significant natural habitats for in-situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation. | Adapt-MitigImpacts | 95 - 101 |
| UNESCO | Adapting to Change (2011) | This is why UNESCO is devoting this edition of the World Heritage Papers series to forest conservation and the green future of our planet. This publication highlights all forest areas inscribed on the UNESCO World Heritage List. To date, the List contains 104 forests, covering a total area of over 75 million hectares (750,000 sq km). Each is a unique ecosystem that provides space for cooperation in science, education, and culture and that is invaluable for the benefit of all. | Adapt-Mitig | 4 - 4 |
| UNESCO | Adapting to Change (2011) | Launched in 2001, UNESCO's World Heritage Forest Programme celebrates the social and cultural value of forests for local communities and conveys the extraordinary natural beauty and biological diversity of these sites. The three Rio Conventions devoted to climate change, biological diversity and combating desertification, along with the United Nations Forum on Forests, all emphasize the pressing need to manage natural resources sustainably. UNESCO works to strengthen the importance of sustainable forest manage�ment, and especially conservation, as green economy activities that contribute to the eradication of poverty. | Adapt-Mitig | 4 - 4 |

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| UNESCO | Adapting to Change (2011) | 3 Joint Foreword Irina Bokova Director-General of UNESCO Sha Zukang United Nations Under-Secretary�General for Economic and Social Affairs and Secretary-General of the UN Conference on Sustainable Development<br>5 T his second State of Conservation of World Heritage Forests report was timed for release during the United Nations International Year of Forests, the motto of which Celebrating Forests for People is very appropriate to the World Heritage Convention – a widely recognized United Nations convention created in large part to ensure that people, both current and future generations, could continue to celebrate and benefit from the outstanding cultural and natural diversity of our world. | Adapt-Mitig | 4 - 5 |
| UNESCO | Adapting to Change (2011) | The first World Heritage forests were inscribed on the World Heritage List in 1978 (Nahanni National Park in Canada, Yellowstone National Park in the USA). As of the 35th session of the Intergovernmental World Heritage Committee in 2011, 104 World Heritage sites covering over 77 million hectares across all biogeographic realms are recognized as World Heritage forest sites – by any standard this is a huge success story for forest conservation. But recognition is only one part of the World Heritage Convention. The complementary part focuses on conservation – a more difficult task. | Adapt-Mitig | 5 - 5 |
| UNESCO | Adapting to Change (2011) | The World Heritage Committee monitors the state of conservation of World Heritage sites, and over the years – as demonstrated in this publication – it has become apparent that World Heritage forests are a particularly vulnerable group of World Heritage sites. | Adapt-Mitig | 5 - 5 |
| UNESCO | Adapting to Change (2011) | The FAO's Global Forest Resource Assessment for 2010 indicates that the trend for including forests in protected areas has accelerated in the last ten years, but that non�protected primary forests – those least disturbed by intensive human activity – continue to be lost at a rate of 4.2 million hectares a year. Extrapolating these trends leads us to conclude that as access to non-protected primary forests becomes ever more difficult, pressure to facilitate access to the remaining protected forests will increase. A brief review of the annual State of Conservation reports produced by the World Heritage Centre and IUCN for the World Heritage Committee reflects this reality in the wide range of threats to listed World Heritage forests. For example, illegal logging and the bushmeat trade pose grave threats to several World Heritage forests because the lands surrounding these sites have often already been depleted of such resources. | Adapt-Mitig | 5 - 5 |
| UNESCO | Adapting to Change (2011) | Beyond the threats that we have grown accustomed to dealing with, climate change is expected to significantly increase the complexities of protected area management in the coming years. Managers will need to redouble their efforts, not only to reduce existing threats but also to look beyond the boundaries of their protected areas so that suitable adaptation strategies may be implemented. These managers will need to develop the capacity and be given the responsibility to engage with agents of wider land use changes in order to achieve this. | Adapt-Mitig | 5 - 5 |
| UNESCO | Adapting to Change (2011) | Introductory Remarks Kishore Rao Director UNESCO World Heritage Centre<br>6 There is an urgent need to find ways in which the World Heritage Convention will, on the one hand, ensure the long term conservation of World Heritage forests, and on the other, encourage the replenishment and sustainable management of accessible forest resources for local communities whose access to resources have been considerably reduced. Recognizing the need to encourage synergies between conservation and development, the World Heritage Committee requested at its 34th session in 2010 that sustainable development measures be integrated into the work of the World Heritage Convention, which has resulted in the approval of an action plan to further this objective. | Adapt-Mitig | 5 - 6 |
| UNESCO | Adapting to Change (2011) | Interesting opportunities are emerging in the case of World Heritage forests. For instance, the emerging global recognition of the role of forests in capturing and storing carbon has led to the development of mechanisms designed to encourage forest conservation, sustainable forest management, and the enhancement of forest carbon stocks through the programme, Reducing Emissions from Deforestation and Forest Degradation (REDD+). | Adapt-Mitig | 6 - 6 |
| UNESCO | Adapting to Change (2011) | In the early stages of development, REDD+ has the potential to compensate communi�ties involved in activities that will result in increased forest cover and better forest management. The link with the conservation of World Heritage forests in the long term is obvious, and worth exploring. | Adapt-Mitig | 6 - 6 |
| UNESCO | Adapting to Change (2011) | Beyond providing an overview of the state of conservation of World Heritage forests in general, this publication attempts to provide some welcome thoughts on the relation�ship between World Heritage forests and their surrounding landscapes, and on mecha�nisms that could be applied to ensure that this relationship is mutually beneficial alongside social, economic and environmental criteria. I am convinced that the World Heritage Convention can be effectively leveraged to bring about such positive contribu�tions, and I look forward to seeing tangible results on the ground. | Adapt-Mitig | 6 - 6 |
| UNESCO | Adapting to Change (2011) | Kishore Rao Director UNESCO World Heritage Centre Adapting to Change – The State of Conservation of World Heritage Forests in 2011<br>7 While many forests predate human existence on earth, forest history is – at its core – about the changing relationships between people and forests, and was the reason behind the choice of the International Year of Forests to celebrate 'Forests for People'. | Adapt-Mitig | 6 - 7 |
| UNESCO | Adapting to Change (2011) | UNESCO World Heritage sites provide a perfect example of how forest conservation can help improve our planet for future generations. With the recent World Heritage designations, sites such as the Ogasawara Islands (Japan) have brought the number of World Heritage Forest sites to 104, putting UNESCO in a unique position to protect some of the world's most precious forests. | Adapt-Mitig | 7 - 7 |

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| UNESCO | Adapting to Change (2011) | World Heritage forests are not immune to these inexorable  forces of change, posing a constant challenge to those  seeking to maintain the rigidly defined OUV for which  these forests were added to the World Heritage List, while  simultaneously incorporating the management flexibility  required by changing conditions. | Adapt-Mitig | 11 - 11 |
| UNESCO | Adapting to Change (2011) | 12  11 Adapting to Change – The State of Conservation of World Heritage Forests in 2011  New Challenges for World Heritage Forests  by Jeffrey A. McNeely Senior Science Advisor, IUCN<br>The changes to forests are far greater than simply an  aesthetic issue of interest, primarily to conservationists. In  fact, every person in the world is affected by what is  happening to forests, even though many remain blissfully  unaware of their dependence. For example, the forests  of the Amazon basin are often considered 'the lungs of  the planet' because of the oxygen they produce through  photosynthesis. But in two of the past five years, drought  conditions have converted the Amazon into a net  consumer of oxygen and producer of carbon dioxide  (Lewis et al., 2011). When droughts or fires hit forests,  even World Heritage status cannot prevent them from  producing more of the greenhouse gases that can accel�erate further climate change. | Adapt-Mitig | 11 - 12 |
| UNESCO | Adapting to Change (2011) | While World Heritage forests may have been designed  and managed to be less vulnerable to fragmentation  caused by humans, this protection is not always perma�nent. For example, in 2009 New Zealand's Mount Aspiring  National Park (part of the South West New Zealand World  Heritage Area) was threatened with losing 20 per cent of  its area to open up mining opportunities (Haggart, 2009). | Adapt-Mitig | 12 - 12 |
| UNESCO | Adapting to Change (2011) | Examples of similar approaches on the World Heritage  forests list include the Gondwana Rainforests of Australia,  the Wet Tropics of Queensland, Brazil's Southeast Atlantic  Forest Reserves and Central Amazon Conservation  Complex, among others. But much more could be done,  perhaps beginning with linking the World Heritage forests  of Central America (Panama's Darien National Park, the  Panama/Costa Rica transboundary Talamanca Range�La Amistad Reserves, Guatemala's Tikal National Park, and  Río Plátano Biosphere Reserve in Honduras) with other  forested areas that do not meet World Heritage criteria   by themselves, but can contribute to the OUV of an entire  landscape. World Heritage could then be seen as the  centrepiece of the Mesoamerican Biological Corridor (Muller and Patry, this volume). The Yellowstone to Yukon  corridor could find ways to link Yellowstone to  Kluane/Wrangell St. Elias/Glacier Bay/Tatsheshin-Alsek, using World Heritage properties – like beads in a natural  necklace: Glacier, Waterton, Nahanni, the Canadian Rocky  Mountain Parks, and Wood Buffalo would be substantial  jewels in such a necklace. Given that such connectivity  plays a role in assuring the OUV of these sites, the World  Heritage Committee might be interested in playing a more  active role in helping bring such systems about. | Adapt-Mitig | 12 - 12 |
| UNESCO | Adapting to Change (2011) | Another form of connectivity is also worth exploring: the  vertical movement on mountains. Already, many World  Heritage forests are cloaking mountains, and the idea is  State of Conservation of World Heritage Forests in 2011   13  1<br>that species responding to climate change will have rela�tively short geographic distances to move, so plants and  animals can more easily change their elevational distri�bution in order to remain in a sort of equilibrium with the  climate (Bush et al., 2004); lower elevation areas could be  added as a sort of buffer zone for possible future expan�sion. World Heritage Mountain Forests that could form the  basis of such an approach include the Greater Blue  Mountains (Australia), Three Parallel Rivers of Yunnan  (China), Los Katios (Colombia), Sangay (Ecuador), Nanda  Devi and Valley of Flowers (India), Lorentz (Indonesia),  Mount Kenya (Kenya), and Kinabalu (Malaysia). A research  and monitoring programme based on World Heritage  Mountain Forests could be highly productive, with useful  comparisons among different geographical variables. | Adapt-Mitig | 12 - 13 |
| UNESCO | Adapting to Change (2011) | On the other hand, World Heritage can also help to  address this problem, especially when neighbouring coun�tries are also involved in the conservation of adjacent sites. | Adapt-Mitig | 13 - 13 |
| UNESCO | Adapting to Change (2011) | Conclusion: How World Heritage forests  can be the catalyst for forest conservation  The International Year of Forests has been established  with the objective of drawing the world's attention to  these critically important ecosystems and their multiple  values for humanity. The hope is that this attention will in  turn lead to greater protection for the remaining forested  areas of our planet. World Heritage forests can play a crit�ical role in this global initiative, as the papers in this publi�cation demonstrate. As forests recognized by govern�ments to be of outstanding universal value, they can open  the minds of governments, corporations, and the public to the magnificence of what remains of our green planet. | Adapt-Mitig | 14 - 14 |
| UNESCO | Adapting to Change (2011) | • Make best use of the management tools available to  World Heritage forests at all levels, from the most  humble forest guard up to the World Heritage  Committee.  Through the long-term monitoring of  World Heritage forests, management responses can be  calibrated to respond to emerging needs, which might  even include changing some boundaries, linking World  Heritage forests through corridors of suitable habitat,  and managing natural forces such as fires, disease  outbreaks, and senescence. Perhaps more importantly,  management techniques developed in World Heritage  forests could be applied to other forests to deal with  increasing human pressures, using techniques such as  the certification of sustainable harvesting (Newsom, this  volume), the use of new technologies to maintain  genetic diversity, controlling the spread of invasive alien  species, and dealing with the anthropogenic spread of  pathogens. | Adapt-Mitig | 14 - 14 |
| UNESCO | Adapting to Change (2011) | The bottom line: eternal vigilance, powerful partnerships,  adaptive management, and strong public support will  provide the best chance for a healthy future for World  Heritage forests. | Adapt-Mitig | 14 - 14 |

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| UNESCO | Adapting to Change (2011) | At its 35th session, the Committee recently decided to extend the Primeval Beech Forests of the Carpathians, originally inscribed in 2007, with a surface area of 29,279 ha. The site now includes the Ancient Beech Forests of Germany, resulting in a total coverage of 33,670 ha in three countries. Forty per cent of World Heritage forests are less than 100,000 hectares in size. Seven are even less than 10,000 hectares. Generally speaking, the smaller the size, the greater the need to ensure effective management in order that the capacity to respond to threats is in place. States Parties should constantly be encouraged to nominate larger forests, or to increase the size of existing World Heritage forests wherever possible. Alternatively, the management of smaller World Heritage sites should receive adequate support and attention in order to ensure that their OUV is fully conserved over time. | Adapt-Mitig | 16 - 17 |
| UNESCO | Adapting to Change (2011) | Relative proportion of 'Danger List' sites that are World Heritage forests When conditions are such that a World Heritage site is faced with threats that may irreparably harm its OUV, the World Heritage Committee may inscribe the site on the List of World Heritage in Danger as a way to draw national and international attention to the site's conservation needs. | Adapt-Mitig | 19 - 19 |
| UNESCO | Adapting to Change (2011) | A site is removed from the list once the Committee is satis�fied that its OUV is no longer under threat. Measuring the proportion of World Heritage forests that are on the Danger List over time provides an indication of the overall trend in the state of conservation – and therefore vulnera�bility – of World Heritage forests. | Adapt-Mitig | 19 - 19 |
| UNESCO | Adapting to Change (2011) | Reporting Trend The Reporting Trend (formerly called the 'Threat Intensity Coefficient') is a function of the number of times the World Heritage Committee reviews the state of conserva�tion of a particular site in the preceding fifteen years, together with the relative distance in time the review has taken place. Thus, if the World Heritage Committee reviewed a site for a few years running, but 10–15 years ago, the trend value will be very low and dropping, this would indicate that the issue in question occurred in the past but was no longer raising concerns. However, a review of a site over the past three to four years will reveal a steep increase in the Reporting Trend value, indicating a current concern that remains an issue. A value of 0 indi�cates the World Heritage Committee had not reviewed the site in the past fifteen years, and a value of 100 indicates that the Committee had studied the state of conservation of the site for each of the past fifteen years. The Reporting Trend values for individual World Heritage forests can be found in Annex III of this publication. | Adapt-Mitig | 19 - 19 |
| UNESCO | Adapting to Change (2011) | World Heritage sites in danger are annually reviewed by the World Heritage Committee. While figure 5 provides an indication of the relative proportion of World Heritage forest sites in danger, figure 6 provides a broader reading of the state of conservation reviewing trends by the World Heritage Committee for all World Heritage forest sites, regardless of whether or not they are on the List of World Heritage sites in Danger. As a result, in contrast to figure 5, which indicates a decline in the proportion of World Heritage forest sites on the Danger List between 1999 and 2005, figure 6 indicates a near constant increase in the level of attention granted by the World Heritage Committee on the state of conservation of World Heritage forest sites. | Adapt-Mitig | 20 - 20 |
| UNESCO | Adapting to Change (2011) | With regard to figure 6, it is clear that World Heritage forest sites have almost consistently drawn increasing attention from the World Heritage Committee in its annual deliberations on the State of Conservation of World Heritage forest sites since 2002. This trend, if not reversed, would indicate increasing conservation concerns for World Heritage forest sites as a whole. | Adapt-Mitig | 20 - 20 |
| UNESCO | Adapting to Change (2011) | Conclusion The indicators noted here, combined with those presented in the 2007 World Heritage Centre report, help improve the understanding of the World Heritage Convention with regard to forest conservation worldwide, as well as providing forest conservation stakeholders a good first quantitative impression on the state of conservation trends for these forests. | Adapt-Mitig | 20 - 20 |
| UNESCO | Adapting to Change (2011) | Collectively, World Heritage forests make a very significant contribution to forest conservation at the global level; as of 2006, 13.3 per cent of all IUCN category I-IV protected forests were recognized under the World Heritage Convention (UNESCO, 2007). These forests are found to be relatively well distributed among the major biogeo�graphic realms of the planet, with 60 per cent over 100,000 ha in size, indicating that the network of World Heritage forests largely consists of what should be fairly resilient forests that are representative of the diversity of the world's forest ecosystems. | Adapt-Mitig | 20 - 20 |
| UNESCO | Adapting to Change (2011) | However, the indicators do point to some concerns regarding the trends in their state of conservation. For example, World Heritage forests are proportionately over�represented on the List of World Heritage in Danger, and they are also steadily attracting more attention over time from the World Heritage Committee in their deliberations over the state of conservation of World Heritage sites. | Adapt-Mitig | 20 - 20 |
| UNESCO | Adapting to Change (2011) | Both these indicators suggest that the conservation of World Heritage forests is increasingly difficult. Further research would be required to investigate the nature of the threats being considered by the World Heritage Committee so as to better define the factors contributing to these trends. | Adapt-Mitig | 20 - 20 |
| UNESCO | Adapting to Change (2011) | Some of the climate related change in plant and animal communities are now apparent (i.e. along the edge of a forest-grassland transition) and others are yet too subtle for us to detect. The changes will become more apparent in the future, and the rate of climate change suggests that 24 2 Adapting to Change – The State of Conservation of World Heritage Forests in 2011 Climate Change and World Heritage Forests by Jim Perry University of Minnesota landscape changes will accelerate. The most likely places to detect changes will be those that are climatically marginal (i.e. transitional areas between forest types or areas where a forest's character is unusual for the region – perhaps having tree cover that is characteristic of a wetter or drier region). | Adapt-Mitig | 22 - 23 |

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| UNESCO | Adapting to Change (2011) | Some modeling efforts accept the average prediction among models as the best answer available, and use that in planning future management. An alternative is to examine variance among models (i.e. standard deviation among models, over the mean of model predictions) as an estimate of uncertainty. If most models predict similar conditions, that ratio will be low and one can be relatively confident in predicted conditions. If that ratio is large, there is less agreement among models and one should have less confidence in the predictions. Uncertainty plays a relatively small role at a given site. However, society has a relatively fixed amount to invest in adaptive management of World Heritage forests. Uncertainty around predicted future conditions should influence where those resources are invested. For example, sites whose climate change predictions are more certain should receive higher priority. | Adapt-Mitig | 23 - 23 |
| UNESCO | Adapting to Change (2011) | Fortunately, other tools exist to help site managers get a better idea of the climate changes that might occur at their site, offering directions for adaptation initiatives. | Adapt-Mitig | 24 - 24 |
| UNESCO | Adapting to Change (2011) | The information required for a given site will always be contextual; a review of the variables that drive vulnerability will allow a site manager to identify the variables most appropriate for his/her site. Many of those data can be collected at coarse spatial scales (i.e. for assessing a site in its surrounding landscape) from remote sensing data such as Google Earth. Geographic Information System (GIS) files of the site will be an invaluable way to identify finer scale spatial pattern, to track and express observed changes in pattern, and to plan management actions (i.e. collabora�tive management with an adjacent land unit). Data avail�ability for GIS applications will vary widely among sites. | Adapt-Mitig | 24 - 24 |
| UNESCO | Adapting to Change (2011) | The HII is calculated for a designated area (i.e. a site itself or a site in its surrounding landscape). The HII can express current and anticipated anthropogenic influences on a site and can guide a site manager in developing proactive management strategies. For example, a site in a land�scape with a high HII might anticipate that climate changes will cause increased incursion on the site. | Adapt-Mitig | 24 - 24 |
| UNESCO | Adapting to Change (2011) | Certainly, the more sensitive forest sites and their compo�nents (i.e. sea level forests, forest-grassland transitions) are noticeably changing. However, many World Heritage forests are large, relatively uniform tracts. Such systems may be strongly resistant to climate change and may deserve increased levels of attention and protection for just that reason. | Adapt-Mitig | 25 - 25 |
| UNESCO | Adapting to Change (2011) | 28 2 Adapting to Change – The State of Conservation of World Heritage Forests in 2011<br>Connectivity and the maintenance of biodiversity in World Heritage forests Many different properties of forest reserves, including their size, continuity or fragmentation, and the degree to which they are connected to other forest areas, affect their usefulness for preserving biodiversity. Connectivity and its inverse – isolation – measure the extent to which a land�scape facilitates or impedes the movement of organisms between habitat patches. It is an important determinant of biodiversity within forests because it strongly influences the rates and patterns of species survival and dispersal, affecting many ecological processes. The ability to move across a region, exploiting resources that vary in space and time, is a fundamental requirement for survival in many species; connectivity between habitat patches facilitates such movement and is often an important contributor to the long-term persistence of such species, and others that depend on them. | Adapt-Mitig | 26 - 27 |
| UNESCO | Adapting to Change (2011) | Whereas the primary focus of the REDD+ mechanism is the creation of incentives for reducing CO2 emissions and enhancing forest carbon stocks in developing coun�tries, it bears great potential to promote actions that contribute to the conservation targets of the Convention on Biological Diversity (CBD) and of the World Heritage Convention (WHC) (SCBD, 2009; von Scheliha et al., 2009; Pistorius et al. 2010). | Adapt-Mitig | 30 - 30 |
| UNESCO | Adapting to Change (2011) | However, these potential additional benefits will not auto�matically be achieved because REDD+ is designed with a quantitative focus on carbon (Brown et al., 2009; Long, 2009; Pistorius et al., 2010). Although the latest REDD+ negotiation text calls for a safeguard to prevent the conversion of natural forests 2, the UNFCCC forest defini�tion in itself does not distinguish between natural forest and forest plantations 3 and thus is a loophole for manage�ment activities that are harmful to forest biodiversity. The same holds true for the sustainable management of forests (SMF), which is promoted by the UNFCCC4 but lacks an adequate definition (Pistorius et al., 2010). | Adapt-Mitig | 30 - 30 |
| UNESCO | Adapting to Change (2011) | Although the biodiversity indicators used to account for positive net-benefits of the projects –as required by the standards – certainly have some shortcomings as their choice is not necessarily based on sound biologically and ecologically considerations (Entenmann, 2010), they exem�plify a practical compromise between ecological require�ments and financial and time constraints. Furthermore, the monitoring activities carried out in REDD+ projects, in Adapting to changes 33 2 5. Standard of the Carbon, Community and Biodiversity Association (CCBA): http://www.climate-standards.org/ 6. For more information: http://planvivo.org Box 1: REDD+ activities in or adjacent to World Heritage forest sites The tropical biome comprises the biggest part of World Heritage forest sites, both in terms of numbers and area, and the total area of World Heritage forest sites increased strongly in the tropics from 1997 to 2006 (Patry et al. 2007). At the same time, there has also been a growing number of conservation activities that apply REDD+ components in tropical forests in or adjacent to World Heritage forest sites. | Adapt-Mitig | 31 - 31 |

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| UNESCO | Adapting to Change (2011) | An example for REDD+ activities emerging adjacent to World Heritage forest sites is a forest carbon programme in the Maya Biosphere Reserve in Guatemala, which is a mosaic landscape of PAs includ�ing community managed forest concessions and the World Heritage forest site Tikal National Park. It is intended to reduce deforestation by using Conservation Agreements and strengthening of community management (Harvey et al. 2010). | Adapt-Mitig | 31 - 31 |
| UNESCO | Adapting to Change (2011) | Connectivity Increasing isolation of PAs has become a big problem over recent decades (DeFries et al., 2005) and is also a great chal�lenge regarding World Heritage forest sites (Patry, 2007). In response, the CBD Programme of Work on Protected Areas 7 adopted the mitigation of ecological isolation and fragmen�tation of PAs as one of its goals. Furthering ecological connectivity is also a recognized climate change adaptation strategy (Thompson et al., 2009). | Adapt-Mitig | 32 - 32 |
| UNESCO | Adapting to Change (2011) | Kasigau Corridor REDD Project, Kenya The Kasigau Corridor REDD Project is located between the Tsavo East National Park and the Tsavo West National Park in Southeast Kenya (Figure 1). REDD+ activities include the protection of the existing carbon stock in the area under threat i.e. by firewood extraction and charcoal production, and some reforestation activities using native trees. | Adapt-Mitig | 32 - 32 |
| UNESCO | Adapting to Change (2011) | According to the Project Design Proposal (WildlifeWorks, 2008; SCS, 2009), the project intends to create a corridor between the two national parks in order to facilitate large mammal migration and to support the conservation of the wildlife and flora within a larger area (Figure 1). | Adapt-Mitig | 32 - 32 |
| UNESCO | Adapting to Change (2011) | Consequently, developing and monitoring indicators for poaching is one central aspect in the monitoring plan of the project. This case highlights that it is not only neces�sary to create a physical connection between parks to facilitate migration, but also to reduce threats. In addition, the corridor needs to meet the ecological requirements of the target species in order to fulfil its connecting function (Fischer et al., 2006; Fischer and Lindenmayer 2007). In this regard, it is important to know the home ranges of the species as the conservation activities aim to ensure that the animals can actually use the corridors. | Adapt-Mitig | 33 - 33 |
| UNESCO | Adapting to Change (2011) | Manú World Heritage Forest Site and National Park, Peru Another example of how REDD+ can be an instrument to contribute to the conservation and connectivity of PAs are the REDD+ activities that are currently being developed in the Madre de Dios region of Peru. These REDD+ activities involve different stakeholder groups and land use/ownership categories like forestry concessions, brazil nut concessions, indigenous communities, national reserves, and private conservation concessions; they take place within or in direct vicinity to PAs in the greater area around the World Heritage forest site Manú National Park (Figure 2) and within the Vilcabamba-Amboró Conservation Corridor (CEPF, 2000). | Adapt-Mitig | 33 - 33 |
| UNESCO | Adapting to Change (2011) | A REDD+ project is currently being implemented in the Private Conservation Concession Los Amigos' (Figure 2, d) with the intention of generating financial means to partly cover the costs of investigating, monitoring and control�ling the area. The concession occupies the watershed of the Los Amigos River and reaches to the Manú River, which enters into the Manú World Heritage forest site. | Adapt-Mitig | 33 - 33 |
| UNESCO | Adapting to Change (2011) | Consequently, the concession protects not only the upstream area of the Watershed of the Los Amigos River, but also to some extent the Manú area, since from the concession it is possible to monitor illegal loggers entering or leaving the World Heritage forest site via the Manú River. So, while REDD+ was not the first incentive to initiate the private conservation concessions, the financial means generated through REDD+ can now contribute to securing the World Heritage forest site. | Adapt-Mitig | 33 - 33 |
| UNESCO | Adapting to Change (2011) | Rainforests of Atsinanana, Madagascar There are currently some efforts to increase the connec�tivity of a series of World Heritage forest sites in Madagascar, connecting the rainforests of Atsinanana consisting of six non-continuous national parks: Marojejy National Park, Masoala National Park, Zahamena National Park, Ranomafana National Park, Andringitra National Park and Andohahela National Park. The Mantadia Corridor Reforestation Initiative, initiated by Conservation International, employs REDD+ and reforestation activities in an area adjacent to the south of Zahamena National Park. This includes the establishment of a new PA that links Zahamena to Mantadia National Park. The Corridor Ankeniheny-Zahamena REDD+ initiative (CAZ) is an area of 425,000 ha and aims to create new PAs that will be zoned into both strict protection areas and areas under commu�nity sustainable management (Harvey et al., 2010). | Adapt-Mitig | 34 - 34 |
| UNESCO | Adapting to Change (2011) | Another conservation project with REDD+ elements, the Fandriana-Vondrozo Corridor Project, is adjacent to the Ranomafana National Park and connects to the Andringitra National Park and Ivohibe Special Reserve. It covers an area of 240,000 ha and has a similar method�ology as CAZ. Another REDD+ initiative, the Makira project, implemented by the Wildlife Conservation Society with support from Conservation International, is adjacent to Masoala National Park (Holmes et al., 2008). | Adapt-Mitig | 34 - 34 |
| UNESCO | Adapting to Change (2011) | These include improved management effectiveness, espe�cially if there is a high historical deforestation rate in the area (Doyle, 2009), the creation of financial incentives for the long-term designation of PAs, and restoration activities in degraded protected areas. | Adapt-Mitig | 34 - 34 |
| UNESCO | Adapting to Change (2011) | Moreover, a scientifically designed, comprehensive and ecologically connected network of representative PAs can be regarded as a viable climate change adaptation strategy (Margules and Pressey 2000; Thompson et al., 2009). | Adapt-Mitig | 35 - 35 |

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| UNESCO | Adapting to Change (2011) | Implementation of REDD+ projects outside PAs or the establishment of new PAs is often restricted by land use conflicts and the high transaction costs of coming to terms with the different land users. Therefore legislative arrange�ments regarding REDD+ have to be made in order to ensure that the location of REDD+ activities is not just determined by the legal and socioeconomic setting, but that they can also be implemented in areas that are strate�gically apt in terms of conservation and connectivity of World Heritage forest sites and other PAs. | Adapt-Mitig | 35 - 35 |
| UNESCO | Adapting to Change (2011) | Further information This study was carried out in the framework of the research project, The Protection of Forests under Global Biodiversity and Climate Policy, hosted by the Institute for Landscape Management and the Institute of Forest and Environmental Policy of Freiburg University, Germany. The project is financially supported by the German Federal Agency for Nature Conservation (BfN) with funds from the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU).10 References Bangladesh Forest Department. 2010. Bangladesh develops forest carbon financing opportunities. Bangladesh Forest Department and US-AID. | Adapt-Mitig | 35 - 35 |
| UNESCO | Adapting to Change (2011) | The mechanism would channel funds from industrialized nations and industries to forested developing countries in order to support conservation interventions that reduce forest based greenhouse gas emissions reductions and increase the sequestration of greenhouse gas from the atmosphere. The proposals are unique because they involve performance based payments—payments would only be delivered if emissions reductions were measured, reported and verified. | Adapt-Mitig | 37 - 37 |
| UNESCO | Adapting to Change (2011) | The mechanism is still under development but will likely involve the transfer of international funds (potentially from a combination of carbon markets, donors and taxes) to participating governments. Governments would then be responsible for national carbon emissions monitoring and accounting, and for a country-wide programme of forest emissions reduction and sequestration. Interventions would be based on national priorities and the opportunity costs of competing land uses (i.e. agriculture, development), but would also likely include enabling conservation policies, protected area establishment and conservation conces�sions, and support and funds disbursement to local forest managers—potentially including World Heritage forests. | Adapt-Mitig | 37 - 37 |
| UNESCO | Adapting to Change (2011) | The process of designating a World Heritage forest considers a wide range of factors but has not traditionally addressed carbon stocks (process reviewed in Patry, 2007a). Nevertheless, forest carbon storage represents a new global conservation priority that merits increased consideration. In the face of rapid REDD+ policy develop�ment and unprecedented donor funding, there is a need to assess the opportunities and limitations of integrating World Heritage forests into future forest carbon emissions mitigation strategies; it cannot be assumed that they will be automatically included into these emissions mitigation strategies. We identify leading issues for World Heritage forest managers interested in upcoming REDD+ policies. | Adapt-Mitig | 37 - 37 |
| UNESCO | Adapting to Change (2011) | Potential for additionality Additionality is a major concept in REDD+ planning— whether activities rewarded by a future REDD+ mechanism represent an improvement over a ‘business as usual’ scenario. It is uncertain whether the financing of existing protected areas represent significant gains for emissions mitigations. Future REDD+ initiatives are likely to maximize resources by directing funds towards countries, forests and sites with the greatest emissions mitigation potentials at the lowest costs. As such, there are some likely limitations to integrating existing World Heritage forests into a future REDD+ mechanism. | Adapt-Mitig | 37 - 37 |
| UNESCO | Adapting to Change (2011) | Even so, REDD+ financial resources could be used to improve the management of protected areas that have historically faced encroachment (Clark, 2008; Oestreicher et al., 2009; Scharleman et al., 2010; Rickets et al., 2010). | Adapt-Mitig | 37 - 37 |
| UNESCO | Adapting to Change (2011) | Potential for cost efficient emissions reductions There is a need to consider the cost efficiency of emissions mitigation achieved through protected areas relative to other REDD+ emissions mitigation approaches, such as reforestation, carbon stock enhancement and sustainable forest management. | Adapt-Mitig | 37 - 37 |
| UNESCO | Adapting to Change (2011) | Adapting to changes 39 2 Integrating World Heritage Forests into a Future REDD+ Mechanism by Jacob Phelps and Edward L. Webb Dept. Biological Sciences, National University of Singapore<br>Protecting threatened, high-carbon density forests is generally considered among the most cost efficient forest based emissions mitigation strategy (i.e. Rickets et al., 2010). This approach requires comparatively limited inputs and can often benefit from economies of scale (Oestreicher et al., 2009). Large protected areas may thus be especially attractive for cost-effective REDD+ interventions. | Adapt-Mitig | 37 - 38 |
| UNESCO | Adapting to Change (2011) | For example, some countries and regions may specifically seek REDD+ interventions that deliver not only emissions reductions, but also livelihood opportunities and additional biodiversity conservation that involve increased costs. | Adapt-Mitig | 38 - 38 |
| UNESCO | Adapting to Change (2011) | The strengths of World Heritage forests Even where World Heritage sites do not have the most cost efficient emissions mitigation strategy, there are still opportunities for REDD+ through World Heritage forests to capture voluntary investment. To date, corporate social responsibility has been a significant motivator of carbon credit purchases (EcoSecurities et al., 2010; Hamilton et al., 2010), and World Heritage forests have the potential to offer charismatic REDD+ projects with substantial addi�tional biodiversity co-benefits. | Adapt-Mitig | 38 - 38 |

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| UNESCO | Adapting to Change (2011) | Emissions mitigation efforts associated with World Heritage forests can also provide valuable guarantees for investors. Well managed protected areas are familiar instruments for the effective conservation of terrestrial carbon stocks (Clark, 2008; Oestreicher et al., 2009; Scharleman et al., 2010). In comparison with other types of prospective REDD+ contracts, such as with individual landholders, World Heritage forests generally benefit from clear tenure, and represent long-term conservation commitments. These factors are important in ensuring permanence emissions reductions that are highly valued within REDD+ contracts. | Adapt-Mitig | 38 - 38 |
| UNESCO | Adapting to Change (2011) | Many World Heritage forests and surrounding landscapes have also been the sites of monitoring and research, with comparatively large amounts of information about their biodiversity, forest types and associated threats, as well as experience with protected areas management and inter�national reporting. This background may provide some sites with a head start for establishing baselines and identi�fying conservation interventions for their surrounding landscapes. They may also provide important lessons learned for national level REDD+ strategy development and REDD+ development in protected areas. | Adapt-Mitig | 38 - 38 |
| UNESCO | Adapting to Change (2011) | Scope for diverse tenure arrangements Yet there remains considerable debate regarding whether traditional protected areas are most the effective and effi�cient approaches to conservation in all situations when compared with community based conservation and other conservation arrangements (Adams et al., 2004). While initial research highlights the importance for REDD+ initia�tives to address local needs and engage local populations (i.e., Oestreicher et al., 2009), it remains uncertain which land tenure and governance arrangements will yield optimal REDD+ outcomes (Clark et al., 2008; Chhatre and Agrawal, 2009; Rickets et al., 2010). | Adapt-Mitig | 38 - 38 |
| UNESCO | Adapting to Change (2011) | REDD+ policies may combine incentives for traditional protected areas with incentives and technical support for community based and co-managed protected areas, and voluntary financial incentives for private landholders and concessionaires (Agrawal et al., 2008). They may also allow for strict conservation areas alongside sites with multiple use objectives, including sustainable management of forests. The challenges, effectiveness, efficiency and trans�action costs associated with REDD+ on different tenure instruments are not well understood and will need to be assessed as World Heritage forests are further integrated into the broader landscape through REDD+. | Adapt-Mitig | 38 - 38 |
| UNESCO | Adapting to Change (2011) | Adapting to changes 41 2<br>The majority of World Heritage forests (66 sites) are in tropical and subtropical developing countries, covering an area of nearly 43 million hectares. These forests protect sizeable stores of terrestrial carbon, important to global climate regulation. The continued and enhanced protection of these sites is potentially relevant to a future REDD+ climate change mitigation mechanism under development through the United Nations Framework Convention on Climate Change (UNFCCC). The World Heritage Committee has vested interests in these large scale, transformational policies as they would affect World Heritage forests across the globe. This paper reviews the status of REDD+ policy development and highlights issues of interest to the World Heritage community, including possible contributions to the REDD+ policy debate. | Adapt-Mitig | 39 - 40 |
| UNESCO | Adapting to Change (2011) | Through a REDD+ mechanism, industrialized countries and carbon emitting industries would provide developing countries with financial incentives to reduce forest based greenhouse gas emissions and increase forest-based removal of greenhouse gases from the atmosphere. A REDD+ mechanism would reward a range of conservation interventions: • Reduced deforestation • Reduced forest degradation • Conservation of existing forest carbon stocks • Enhancement of forest carbon stocks (i.e. through tree planting) • Sustainable management of forests (i.e. selective cutting and replanting) The UNFCCC has entered its sixth year of negotiations on the design of a future REDD+ mechanism. Despite the prolonged process, recent pledges for billions of dollars in donor support have spurred rapid REDD+ policy develop�ments both within and outside the UNFCCC. Nearly every one of the large, international non-governmental organi�zations has developed a REDD+ programme. Dozens of REDD+ pilot projects have emerged, and more than two dozen developing countries are in the process of devel�oping REDD+ national strategies. The engagement of World Heritage forests with a future REDD+ mechanism would promise harmonization with broader environmental conservation goals, and could offer a novel and large source of funding for forest managers. Yet there are a number of remaining, unresolved policy and methodolog�ical issues. | Adapt-Mitig | 40 - 40 |
| UNESCO | Adapting to Change (2011) | The UNFCCC process To date, no formal concrete REDD+ mechanism has been established through the UNFCCC. Nevertheless, the UNFCCC 16th Conference of Parties (COP16) held in Cancun, Mexico, in late 2010 demonstrated considerable political support for REDD+. In fact, REDD+ is one of the areas of broadest consensus within the UNFCCC climate negotiations (UNFCCC, 2010). The resulting Cancun Agreement defined a broad scope for REDD+, urging developing country Parties not only to reduce deforestation and forest degradation, but also to plan for the conserva�tion and enhancement of existing forest carbon stocks and the sustainable management of forests. While this broad�ened scope increased opportunities for participation, a remaining challenge is to specifically define the land uses that would be rewarded through a future REDD+ mecha�nism. The Cancun Agreements further ensured continued REDD+ negotiations among the UNFCCC Parties and early development of REDD+ pilot projects, setting guidelines for future policy development (including rudimentary safe�guards), and setting ambitious pledges for donor finance. | Adapt-Mitig | 40 - 40 |

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| UNESCO | Adapting to Change (2011) | These efforts include dozens of pilot projects, which are reforming forest governance strategies, pioneering forest and carbon inventory accounting and monitoring tech�niques, and developing strategies to identify and limit the drivers of deforestation and degradation. As such, oppor�tunities to engage in REDD+ are not limited to the official 42 2 Adapting to Change – The State of Conservation of World Heritage Forests in 2011 What World Heritage Can Offer REDD+ Policy Development by Jacob Phelps and Edward L. Webb Dept. Biological Sciences, National University of Singapore<br>UN process or policy development. There is also a wide�spread need for pilot initiatives and best practices in reducing deforestation and forest degradation, including through protected areas management. | Adapt-Mitig | 40 - 41 |
| UNESCO | Adapting to Change (2011) | Despite the emergence of an international REDD+ frame�work, the independent development of national REDD+ strategies and the identification of nationally appropriate emissions mitigation strategies suggest that approaches on the ground may vary considerably. The role of protected areas and landscape level planning in reducing forest based emissions is also likely to vary based on national priorities, resources and leadership. External donor support and Party commitments to existing international agree�ments are also likely to be pivotal in determining countries' REDD+ strategies. | Adapt-Mitig | 41 - 41 |
| UNESCO | Adapting to Change (2011) | REDD+ is principally concerned with carbon sequestration and the non-release of forest carbon, rather than with forest conservation in and of itself. While protecting forests generally equates to positive biodiversity outcomes, ensuring, measuring, monitoring and reporting additional biodiversity and social co-benefits involves increased costs. | Adapt-Mitig | 41 - 41 |
| UNESCO | Adapting to Change (2011) | While the UNFCCC promotes co-benefits, these additional costs will likely be externalized. The financial and technical support required to deliver co-benefits will likely come from donors and voluntary buyers that favour REDD+ interventions with multiple benefits. However, it is uncer�tain whether a future REDD+ mechanism will recruit adequate voluntary and donor resources to deliver addi�tional co-benefits (Phelps et al., 2011). As a result, some policy makers, including the CBD Secretariat, are advo�cating for a REDD+ mechanism that integrates not only safeguards, but also internalizes the costs of delivering additional livelihood and biodiversity co-benefits (i.e. CBD and GIZ, 2011). The co-benefits debate, in parallel with negotiations on REDD+ safeguards, will largely dictate the conservation potential of REDD+ interventions and influ�ence the involvement of World Heritage forests. | Adapt-Mitig | 41 - 41 |
| UNESCO | Adapting to Change (2011) | The status of REDD+ funding REDD+ offers unprecedented resources for forest conser�vation. During the mid-1990s, annual spending on protected areas in developing countries totaled approxi�mately US$600 million (James et al., 2001). In contrast, donors have already pledged over US$4 billion in finance for early REDD+ planning in tropical developing coun�tries, most by 2012 (Ballesteros et al., 2010). Investments could grow considerably, as the estimated annual cost of reducing tropical deforestation by 50 per cent is between US$12–35 billion (compiled in CI et al., 2010). The recent establishment of the UN Green Climate Fund, with a target of providing US$100 million per year for climate change mitigation and adaptation in developing coun�tries, including support for REDD+, suggests that greater funding is forthcoming (UNFCCC, 2010). | Adapt-Mitig | 41 - 41 |
| UNESCO | Adapting to Change (2011) | • There are still relatively few international guidelines for REDD+ development. The Committee could help to provide international statutory incentives for ensuring that Member States implement REDD+ within the context of landscape level management in a way that enhances protected area networks, and has clear safeguards. | Adapt-Mitig | 42 - 42 |
| UNESCO | Adapting to Change (2011) | Possible national-level engagement As Member States develop National REDD+ Strategies, the World Heritage Centre is positioned not only to provide general guidelines, but also technical support to help ensure integration of World Heritage forests, best practices and landscape level management. The broader World Heritage community has also designed and managed successful protected area networks, identified drivers of deforestation and degradation, and designed conserva�tion interventions. These experiences may feed into national level REDD+ planning efforts. | Adapt-Mitig | 42 - 42 |
| UNESCO | Adapting to Change (2011) | During a period when a great number of conservation agencies are jockeying for position within the REDD+ process, the World Heritage Community is pressed to iden�tify its opportunities, responsibilities and capacity for engaging in global and domestic REDD+ policy formulation. | Adapt-Mitig | 42 - 42 |
| UNESCO | Adapting to Change (2011) | http://www.cbd.int/doc/publications/for-redd-en.pdf Conservation International, Environmental Defense Fund, Natural Resources Defense Council, Rainforest Alliance, The Nature Conservancy, Union of Concerned Scientists, Wildlife Conservation Society, Woods Hole Research Center. 2010. Financing Options for REDD. Washington, D.C. Conservation International. | Adapt-Mitig | 42 - 42 |
| UNESCO | Adapting to Change (2011) | For forestry operations located within the buffer area of a World Heritage site, there are many elements of the FSC standards that, when implemented, could improve the ability of the site to function as an intact and robust ecosystem. These include requirements that FSC-certified forestry operations identify and conserve High Conservation Value Forests (HCVFs) and habitats for threatened and endangered species, and include having systems in place to prevent fires and the movement of invasive species, paying workers fairly, and ensuring that local communities benefit from employment and access to the forest for cultural practices and the harvesting of non-timber forest products. These sustainable forestry practices, within a landscape matrix, can also serve as an important link between multiple protected areas. | Adapt-Mitig | 44 - 44 |

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| UNESCO | Adapting to Change (2011) | Río Plátano Biosphere Reserve At 500,000 hectares in size, the Río Plátano reserve is the largest remaining undisturbed tropical rainforest in Honduras, and one of the few remaining humid tropical rainforests in Central America. The majority of the area is covered by mature broadleaf forests, with pine savannahs, mangroves, swamp forest and hardwood gallery forest found along the Plátano river and its tributaries. Over 2,000 indigenous people have preserved their traditional way of life within this mountainous landscape.12 This World Heritage site is under threat from agricultural expansion into the southern and western sides of the reserve and illegal logging for species such as mahogany (Swietenia macrophylla). Wildlife within the reserve is under threat from uncontrolled commercial hunting and the introduction of exotic species.13 A lack of park staff has been cited as compounding the problem.14 Two RA/FSC-certified forestry operations are located within or adjacent to the Río Plátano Biosphere Reserve (RPBR). The first is UNICAF-BRP (Union of Agro-Forestry Cooperatives of the Río Plátano Biosphere Reserve) an organization that was created in 2008 with the goal of sustainable management and the sale of timber and non-timber forest products, environmental services such as carbon retention and sequestration, ecotourism and others. The group is composed of five FSC-certified oper�ations, each managing its own forest resources within the RPBR's buffer and cultural zone. | Adapt-Mitig | 46 - 46 |
| UNESCO | Adapting to Change (2011) | Afterwards, the Amur branch of WWF-Russia, aided with the identification and mapping of the key habitats, biotopes and High Conservation Value Forests, developed an ecological monitoring system and held training courses with company staff. | Adapt-Mitig | 49 - 49 |
| UNESCO | Adapting to Change (2011) | Corrective Action Requests related to the seven categories we examined mainly centred on the identification, mapping and conservation of High Conservation Value Forests, and potential habitats of rare and endangered plant and animal species. | Adapt-Mitig | 49 - 49 |
| UNESCO | Adapting to Change (2011) | All four RA/FSC-certified operations were assessed between May 2001 and December 2003 and have been certified since. All combined, they were issued 126 major CARs and 24 minor CARs 23. Many of these CARs required improved assessment and protection of HCVFs, as well as the safeguarding of rare, threatened and endangered species. One operation was required to map its members' conservation areas, and adjust or add areas to the conser�vation zone to fill gaps and improve landscape level conservation. Another operation was required to create corridors for the movement of rare, threatened and endangered species. One CAR was issued that required training on firefighting, and the acquisition of firefighting equipment. | Adapt-Mitig | 50 - 50 |
| UNESCO | Adapting to Change (2011) | Corrective Action Requests that addressed worker and community issues included the requirement that all workers have access to social security benefits and first aid kits that are adequately stocked with supplies and medi�cine. Local communities will also benefit from the require�ment that chicleros and xateros – the men and women who harvest chicle and xate – are consulted with, and their opinions incorporated into forest management plans. | Adapt-Mitig | 50 - 50 |
| UNESCO | Adapting to Change (2011) | Based on this analysis, the future potential for forest certi�fication to enhance the functionality and integrity of World Heritage sites seems high. By explicitly targeting the areas around World Heritage sites and other protected areas for RA/FSC certification, the benefits of certified forestry will likely extend beyond the operation's bound�aries and into nearby forests and communities.<br>Most frameworks and initiatives that seek the conserva�tion of natural and cultural landscapes recognize the complexities and challenges involved, namely, the need to reduce the threats to natural habitats while promoting and sustaining the livelihoods of people living within such landscapes. In seeking to deconstruct these complexities, we are forced to resolve issues such as how to define forest, how to manage forests under dynamic conditions with incomplete system knowledge, and how to deliver the benefits of conservation in an equitable manner. | Adapt-Mitig | 51 - 52 |
| UNESCO | Adapting to Change (2011) | These issues are neither simple, nor can they be properly resolved by any single disciplinary approach. Indeed, recognition of this by, for example, the World Heritage Convention and the Convention on Biological Diversity (see for instance, the report on World Heritage and Sustainable Development), has led to the promotion of ecosystem management approaches that seek, among other things, to promote equity and benefit-sharing though the integration of local stakeholders into decision�making, which necessarily requires the consideration of socio-economic and institutional concerns along with the ecological concerns that provided the primary impetus for these conventions. In this light, successful conservation is less about biophysical aspects and rather more about the management and adaptation of governance systems across societal scales. | Adapt-Mitig | 52 - 52 |
| UNESCO | Adapting to Change (2011) | This is coupled with the observation that the conservation of forested habitats is not exclusively confined to the preservation of large and relatively undisturbed tracts of primary forest, but now also needs to include the often heterogeneous landscape matrices. While some tropical landscapes have been converted to large-scale intensive crop production or pasture, many others are comprised of diverse agricultural land uses, as well as natural habitat features such as rivers and streams, wetlands, natural grasslands, and forest remnants. The persistence of non�protected natural elements in these human dominated landscapes is invariably the result of long-standing local management practices, which may be imbued with cultural associations as well as livelihood needs. Further, in many tropical locations the distinction between agricul�tural and natural lands is often not so clear; many agricul�tural land uses, including various forms of shifting cultiva�tion and agroforestry, retain native trees and associated biodiversity to a considerable extent. Similarly, there is broad acceptance that forested areas can support liveli�hoods as well as biodiversity, particularly through the provision of non-timber forest products and various ecosystem services. In other words, anthropogenic land�scape mosaics that support biodiversity, ecosystem services and livelihoods, and encompass a wide range of cultural as well as biological values, are also worthy of conservation attention. This is particularly the case now, as many of these landscape mosaics are increasingly threatened by agricultural intensification. | Adapt-Mitig | 52 - 52 |

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| UNESCO | Adapting to Change (2011) | Existing frameworks for participatory landscape management Recognizing these issues is, of course, not sufficient to meet the various demands of conservation and local liveli�hoods. Systems of management need to be developed and implemented to account for the complexities and uncertainties inherent in any holistic land management programme. The main objectives of such a programme is the environmental sustainability and comparative prof�itability of local livelihoods, coupled with the conservation of biodiversity and the continued provision of ecosystem services to local, regional and global communities. | Adapt-Mitig | 52 - 52 |
| UNESCO | Adapting to Change (2011) | There are several precedents for such programmes. The Model Forest approach (Box 1) leads from the bottom up and promotes sustainable forest management through local governance based on participation by all stake�holders. By recognizing a plurality of resource needs and rights, and by jointly identifying the barriers and challenges to meeting stakeholder aspirations (i.e. jobs, NTFP, recre�ation, hunting, wood, biodiversity conservation), it seeks to create a shared local vision for development from which all stakeholders would benefit. Other approaches have their origins in international research institutions such as ICRAF's Rewarding Upland Poor for Environmental Services (RUPES) initiative, which seeks to build capacity among poor small�holder communities to access and benefit from payments for environmental service schemes (Box 2). | Adapt-Mitig | 52 - 52 |
| UNESCO | Adapting to Change (2011) | These schemes all seek broadly similar objectives, but they also face a similar set of challenges. Principle among these is the degree to which they are able to empower local communities to manage their landscapes in order to 54 2 Adapting to Change – The State of Conservation of World Heritage Forests in 2011 Enhancing Community Management of World Heritage Forests Through Landscape Labelling by Jaboury Ghazoul Institute of Terrestrial Ecosystems, Department of Environmental Sciences, ETH Zurich, Switzerland<br>deliver the broad objectives to which these approaches subscribe. Biosphere reserves provide government spon�sored international visibility, but the approach is largely top-down in that activities in core areas are constrained by regulations determined by the reserve's authorities, albeit often in consultation with agriculture and forestry authori�ties, administrations for water management, as well as local governments. The functioning of biosphere reserves is also heavily dependent on financial support from central governments, but when financial and political support is reduced the extent of participatory efforts declines. | Adapt-Mitig | 52 - 53 |
| UNESCO | Adapting to Change (2011) | Biosphere reserve administrations might also be perceived by local communities to be too closely tied to nature protection objectives and therefore not a neutral arbiter. | Adapt-Mitig | 53 - 53 |
| UNESCO | Adapting to Change (2011) | The Model Forest and the Community-based Payments for Environmental Service schemes must include effective locally inclusive and broadly representative institutions that provide accountability of local representation for decision�making and conflict management. These organizations need to be sensitive to gender issues and represent the interests of the poorest members of society. Trust between individuals, communities, regional and national govern�ments, and external actors is a basic condition for the successful outcome of negotiated agreements. Such conditions might be difficult to establish in community led approaches on account of the power and influence invested in certain stakeholder groups, social or ethnic classes, or individuals. Further, the success of these schemes assumes an adequate financing framework. The Model Forest promotes rural entrepreneurship through capacity-building and skills development, but commercial outcomes might conflict with forest and natural resource conservation objectives. Community-based Payments for Environmental Service schemes suffer from relatively high transaction costs of engagement that might limit small�holder participation. | Adapt-Mitig | 53 - 53 |
| UNESCO | Adapting to Change (2011) | Landscape labelling Building on this foundation is the concept of Landscape Labelling, which proposes that managed rural landscapes that are recognized to be delivering ecosystem services (based on local and regional evaluation by appropriate institutions) should be acknowledged as such through the designation of an exclusive 'Landscape Label' applicable across the whole landscape. A Landscape Label would represent the delivery of various ecosystem services, and thus be the conduit through which payments for ecosystem services to appropriate community-based organizations are made. Such payments would incentivize the continued delivery of these services through commu�nity-based management of the landscape. The Landscape Label could additionally be used to identify a product as originating from an ecosystem service-providing region, as Adapting to changes 55 2 Box 2. Community-based Payments for Environmental Services Reward schemes based on payments for environ�mental services (PES) seek to incentivize conserva�tion. Such schemes are often inefficient on private smallholdings (typically less than 50 ha), and this many poor smallholders are excluded from accessing such benefits. ICRAF's Rewarding Upland Poor for Environmental Services (RUPES) programme and the similar Pro-poor Rewards for Environmental Services in Africa (PRESA) (ICRAF 2008) seek to promote community-based action to socially and politically empower communities to engage in PES schemes. | Adapt-Mitig | 53 - 53 |

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| UNESCO | Adapting to Change (2011) | Box 1. Model Forest In Model Forests all stakeholders within an agricul�tural and forested landscape mosaic collaborate to manage the landscape's natural resources. Their management approach is based on their shared cultural history, and recognition of the landscape's natural values as well as their current and future economic needs. The collaborative partnership across stakeholders seeks to define sustainability in the local context, and then develops governance structures and strategic plans, to implement a set of common goals that seek to integrate economic and non-economic priorities. Important features of Model Forests are the comprehensiveness of their approach, the landscape scale of their oper�ation, and their inclusiveness. Model Forests are driven by bottom-up processes in that local stake�holders collectively set their own priorities, relating to conservation of biodiversity, economic enter�prise, public education, and infrastructural develop�ment. As such, the system is flexible and allows for local adaptation.<br>well as serve to symbolize the wide variety of ecosystem services provided by the landscape. The Landscape Label could also represent and indeed publicize the cultural and symbolic attributes of the landscape, as defined by local communities, thereby helping to define its heritage value and uniqueness for people beyond the landscape. This in turn would provide greater recognition to communities, and help to empower them in negotiations with outside agencies (including government or companies), while promoting landscape recognition that could serve to generate new livelihood opportunities through, for example, tourism. | Adapt-Mitig | 53 - 54 |
| UNESCO | Adapting to Change (2011) | A Landscape Labelling approach therefore provides a mechanism by which payments for environmental services are delivered to the community on the basis of effective landscape management. Individual landowners and producers additionally benefit from higher market recogni�tion of their products through the use of the Landscape Label as a certificate of good land and environmental management. Thus a Landscape Label potentially permits producer communities to improve market recognition, secure premium payments, gain access to niche markets, and attain market benefits for minor products by associa�tion through the label with more commercially important products. The derived benefits can, in turn, secure an incentive for managing the landscape in such a way as to continue to meet the ecosystem service criteria required for certification. Landscape Labelling potentially has other benefits such as reducing transaction costs, improving inclusivity and equity, cheaper conditionality determina�tion, allowing more flexibility in response to changing market environments, and providing social pressure to limit freeloading. | Adapt-Mitig | 54 - 54 |
| UNESCO | Adapting to Change (2011) | Landscape Labelling affords flexibility in management at the landscape scale. Thus one limitation of Payment for Environmental Services (PES) schemes is that landowners are contractually bound to restrict their land use activities, and are therefore limited in the extent to which they can respond to changing commodity markets. Assessing ecosystem service provision at the aggregated scale of the landscape, as proposed by Landscape Labelling, allows greater flexibility with regard to land use decisions. | Adapt-Mitig | 54 - 54 |
| UNESCO | Adapting to Change (2011) | This raises the potential for landscape wide offset markets, permitting landowners to offset certain environmentally damaging activities while retaining the benefits of Landscape Labelling. Such flexibility is likely to make Landscape Labelling more attractive to wide participation, as there is recognition that high opportunity costs can be accommodated through reforestation or improved forest protection elsewhere within the landscape where opportu�nity costs are less. | Adapt-Mitig | 54 - 54 |
| UNESCO | Adapting to Change (2011) | Applying Landscape Labelling concepts to World Heritage forests World Heritage forest designation is applied to regions where forest ecosystems contribute to the site's outstanding universal value. The broad objectives of World Heritage forest management must respond to threats (including invasive species, pollution of waterways, and forest conversion to agriculture) but in the context of human development ambitions. This in turn requires that different land uses, values, and management approaches be defined in consultation with local stakeholders. | Adapt-Mitig | 54 - 54 |
| UNESCO | Adapting to Change (2011) | Landscape Labelling can provide a mechanism by which local stakeholders can be more effectively integrated in World Heritage forest management. The World Heritage forest can provide the logical framework for a sustainable landscape management. For example, the overriding prin�ciple for the landscape might be 'management to contribute to the long term conservation of the World Heritage forest, by maintaining its ecological connectivity with the broader landscape context'. Local landowners, NGOs, and community institutions that work towards this goal would be credited with the use of an exclusive 'World Heritage Conservation Landscape' label or certifi�cate, which could be exploited for commercial purposes such as product labelling or attracting payments for ecosystem services. | Adapt-Mitig | 54 - 54 |

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| UNESCO | Adapting to Change (2011) | Landscape Labelling approaches rely on strong and repre�sentative community institutions responsible for coordi�nating activities across the landscape as well as the equi�table distribution of benefits through investments in community programmes and infrastructure. Often this is likely to require the strengthening of existing local stake�holder networks, and perhaps the establishment of new ones. The Model Forest approach thus provides an existing system to emulate. The adoption of a RUPES approach to the dissemination of ecosystem service payments with financial benefits invested through community based organizations for infrastructure development and social 56 2 Adapting to Change – The State of Conservation of World Heritage Forests in 2011 projects would ensure the broad and equitable distribution of benefits. Thus inclusivity and equitable distribution of benefits to all community members is an important element of Landscape Labelling. By allocating payments from ecosystem service buyers to community-based organiza�tions, and investing in social and community projects, the Landscape Labelling approach provides the potential to secure benefits to all community members including the landless poor. While these benefits are indirect, they may be important in providing improved access to markets, better education and healthcare, micro-insurance, and so on. | Adapt-Mitig | 54 - 55 |
| UNESCO | Adapting to Change (2011) | People living within the broader World Heritage forest landscapes might additionally benefit through the use of a World Heritage Conservation Landscape label by which their products could be differentiated from others in the market place, thereby securing greater market access or possibly a price premium. This might be best applied to products with a large international market, such as coffee and cocoa, but could conceivably be applied more gener�ally. Indeed, the Landscape Label need not be restricted to a particular product, as is the case with most certification or labelling initiatives, but could be associated with a land�scape. Hence, any product that is derived from that land�scape can use the label to indicate that it has been produced under a management system that continues to provide ecosystem services. This provides benefits in terms of market recognition – and potentially price premiums – to all farmers regardless of the type of goods produced. | Adapt-Mitig | 55 - 55 |
| UNESCO | Adapting to Change (2011) | The management of the World Heritage forest landscape, through the collective action of the communities living within it, would need to recognize and respond to the criteria of the World Heritage forest designation if the benefits of PES funds and the World Heritage forest label are to be maintained. These benefits, provided they are sufficient to overcome the costs (including opportunity costs), would therefore provide an incentive for local communities to work closely and align themselves with the World Heritage objectives to ensure the sustainability of the landscape. The success of community-wide schemes is dependent on effective institutional structures that provide appropriate negotiation and communication pathways among the variety of community organizations. A diversity of community-based organizations and interests is typical of many rural landscapes; ensuring effective interaction among such organizations is one of the most serious chal�lenges to the implementation of landscape-level PES processes. The success of the Landscape Labelling approach rests on the effective functioning of such organizations, and cooperation among them. Payments to support a certi�fied landscape are expected to be made to appropriate community institutions responsible for making investment decisions. Conflicts among community-based organizations and corruption within them is perhaps the single most important threat to the successful implementation of Landscape Labelling. Nevertheless, there is considerable awareness and knowledge regarding empowerment of and collaboration among community-based organizations, and examples of collaborative networks to secure wider community benefits are known. These include the Model Forest system, which encompasses a network of stake�holders that share the common goal of sustainable land�scape and forest management with a view to preserving ecosystem services and local livelihoods. | Adapt-Mitig | 55 - 55 |
| UNESCO | Adapting to Change (2011) | Indeed, there is increasing acceptance that forested land�scapes, encompassing other forms of land use and habitat cover than just forests, should be the focus of manage�ment attention and conservation. This implicitly recognizes humans as part of those landscapes. This thinking has led to a more inclusive and bottom up approach to manage�ment and conservation that integrates local stakeholder value systems and decision-making. | Adapt-Mitig | 55 - 55 |
| UNESCO | Adapting to Change (2011) | The Landscape Labelling approach seeks to provide mech�anisms by which such a bottom-up approach is linked to an internationally recognized programme though which access to PES funding might be promoted and ultimately realized. Thus well conserved World Heritage forests can form the basis of a rigorous logical framework against which sustainable development at the landscape level can be constructed. A healthy landscape, contributing to the long-term conservation of a World Heritage forest by, for example, promoting land use systems that improve ecological connectivity and that secure its integrity, could be formally recognized as such. The contribution of local communities to this objective, through appropriate land management, could be evaluated and recognized by a label through which PES might be sought and secured. | Adapt-Mitig | 55 - 55 |
| UNESCO | Adapting to Change (2011) | Moreover, through the use of the World Heritage forest name and label, the Landscape Labelling approach offers a second independent mechanism of securing market benefits from products emerging from a World Heritage forest. In this way, local communities might be able to secure real benefits from World Heritage status, and therefore gain increased incentive for its effective management. The Landscape Labelling approach suggests a strong community identity and effective local networks and institutions. The Model Forest Trust Network provides an example on how such identity and coherence might be developed and sustained. | Adapt-Mitig | 55 - 55 |

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| UNESCO | Adapting to Change (2011) | 3 Jiuzhaigou Valley Scenic and Historic Interest Area, China © Andy Leong 59 Introduction The Convention on Biological Diversity (CBD) is an inter�national treaty for the conservation and sustainable use of biodiversity, and the fair and equitable sharing of benefits arising out of the utilization of genetic resources. Over the years, the Conference of the Parties to the CBD devel�oped programmes of work on thematic areas, correspon�ding to the major biomes the world. It also initiated work on key cross-cutting issues that are of relevance to all thematic areas. | Adapt-Mitig | 56 - 57 |
| UNESCO | Adapting to Change (2011) | The CBD's programme of work on forest biodiversity (CBD decision VI/22), for example, promotes measures to enable the conservation and sustainable use of forest resources and the equitable sharing of benefits arising from their use. Similarly, the CBD's programme of work on protected areas (decision VII/28) promotes the establishment and maintenance of comprehensive, effectively managed, and ecologically representative national and regional systems of forest protected areas. | Adapt-Mitig | 57 - 57 |
| UNESCO | Adapting to Change (2011) | Other targets that are also relevant to forests, aim to eliminate negative incentives harmful to biodiversity, apply positive incentives for conservation and sustainable use (Target 3), and to restore and safeguard ecosystems that provide essential services and contribute to health, livelihoods and well-being, in particular for women, Global Governance – What is the relationship between World Heritage Forests and Global Governance processes? | Adapt-Mitig | 58 - 58 |
| UNESCO | Adapting to Change (2011) | • Decision X/32 on sustainable use of biodiversity invites Parties and other governments to implement the recom�mendations for the sustainable use and conservation of bushmeat species, developed by the CBD Liaison Group on Bushmeat in 2009. The decision requests the Executive Secretary to develop through the Liaison Group, options for small-scale food and income alterna�tives to bushmeat hunting that are based on the sustain�able use of biodiversity. The decision also requests the Executive Secretary to compile information on how to improve the sustainable use of biodiversity in a land�scape perspective, including sectoral policies, interna�tional guidelines, and best practices for sustainable agri�culture and forestry. | Adapt-Mitig | 59 - 59 |
| UNESCO | Adapting to Change (2011) | Key forest related activities of the CBD Secretariat ITTO and CBD Initiative Based on a Memorandum of Understanding and with generous funding from the Government of Japan, the Secretariat of the International Tropical Timber Organiza�tion (ITTO) and the CBD started a joint initiative for the conservation and sustainable use of tropical forest bio�diversity. The initiative supports the implementation of the CBD programme of work on forest biodiversity in ITTO producer member countries through specific country proj�ects related to capacity building, technical support and guidance. It builds on the experiences of the 'Friends of the PoWPA' in support of the CBD programme of work on protected areas. | Adapt-Mitig | 61 - 61 |
| UNESCO | Adapting to Change (2011) | The implementation of the initiative is led by ITTO in close consultation with the CBD Secretariat and the Government of Japan. The initiative prioritizes activities related to relevant goals identified in the CBD's Strategic Plan. The country projects of the initiative focus inter alia on the linkages between forest biodiversity and climate change, biodiversity conservation in production forests, and transboundary conservation of tropical forest resources. The focus on transboundary conservation, in particular, may present new opportunities for existing or future World Heritage sites in tropical forests. | Adapt-Mitig | 61 - 61 |
| UNESCO | Adapting to Change (2011) | Conclusion The decisions of the Conference of the Parties to the Convention on Biological Diversity (CBD), in particular the Strategic Plan for Biodiversity 2011–2020, are highly relevant for the future management and possible expan�sion of the network of protected forests globally, including World Heritage forests and the Man and Biosphere Programme. The International Decade for Biodiversity 2011-2020 will be a decisive period in setting the right policies through National Biodiversity Strategies and Action Plans and other relevant instruments for a sustainable future, and for achieving the vision of the Strategic Plan that states, "By 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and deliv�ering benefits essential for all people." 64 3 Adapting to Change – The State of Conservation of World Heritage Forests in 2011 3. For more information on the CBD LifeWeb Initiative, please refer to: http://www.cbd.int/lifeweb On 2 February 2011 the Secretariat of the United Nations Forum on Forests launched the International Year of Forests, also known as Forests 2011, to celebrate the essential role that forests play in the lives of billions. The network of World Heritage forests provides a unique plat�form where the benefits of forests can be better harnessed to both improve the well-being of people and the health of forests around the world. | Adapt-Mitig | 61 - 62 |
| UNESCO | Adapting to Change (2011) | Despite this, the social and cultural values of forests are only rarely mentioned. Two main reasons could be put forward to account for this. First, local people have long been held as culprits of environmental degradation, and particularly of deforestation. For much of the nineteenth and twentieth centuries, Western conservationists saw humans as the antithesis of nature, and believed that the former could only harm the latter. In more recent decades, both decision-makers and experts further emphasized the allegedly destructive role of local communities in a bid to wrest away both management and knowledge of forests respectively from local hands. In particular, shifting cultiva�tion (also known as slash-and-burn) and extraction of wood and non-timber forest products by communities for subsistence purposes were highlighted as the primary causes of deforestation. This also had the advantage of turning the attention away from other causes that included industrial logging and large-scale agriculture. | Adapt-Mitig | 62 - 62 |

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| UNESCO | Adapting to Change (2011) | While experts deconstructed the discourse denouncing communities as the primary culprits of deforestation1, decision-makers began to see the benefits that community participation could have in all forms of sustainable forest management, including conservation. Despite such advances, however, local communities continue to be largely marginalized and their rights to access the multiple values of forests frequently denied, for the simple reason that they do not have the capacity to influence decision�making processes. | Adapt-Mitig | 62 - 62 |
| UNESCO | Adapting to Change (2011) | 2. IUCN (2009). Applying the forests-poverty toolkit in the village of Tenkodogo, Sablogo Forest. Ouagadougou (Burkina Faso): The World Conservation Union. example, if economists limited themselves to the cash value of forests for local communities, they would only see about a fifth of the total value – the mere tip of the iceberg. | Adapt-Mitig | 62 - 63 |
| UNESCO | Adapting to Change (2011) | To cite just one example in Central Africa, the growing taste of urban populations for bushmeat has encouraged members of rural communities to contribute to the alarming depletion of forest wildlife well beyond their subsistence needs. Likewise, in eastern Democratic Republic of the Congo, the participation of communities in the charcoal trade to provide fuel to the region's cities has become one of the greatest threats to a number of protected areas, including the World Heritage Okapi Wildlife Reserve. It is therefore essential to strike a balance between the different functions of forests so as to ensure that the use of forests, whether by local communities or large-scale industries, remains compatible with the preservation of ecosystem services, particularly in the world's most ecologically valuable forests such as those inscribed on the World Heritage List. | Adapt-Mitig | 63 - 63 |
| UNESCO | Adapting to Change (2011) | 67 3 3. IUCN Category Ia: Strict Nature Reserves; Ib: Wilderness Areas; II: National Parks. Due to the great fragility of these natural ecosystems, the use of the environment by local communities is often extremely restricted or simply non-existent in these categories.<br>'Forests for People', the main theme of the 2011 International Year of Forests (IYF), highlights the ecolog�ical, economic and cultural importance of forests for human life as well as the central role of people in the conservation and sustainable management of the world's forests. By placing people at the heart of the current global debate on forests, IYF places emphasis on the power of human action not only as part of the problem, but also as part of the solution. | Adapt-Mitig | 64 - 65 |
| UNESCO | Adapting to Change (2011) | During the past four decades, the biosphere reserve concept, which originated in the framework of the MAB Programme, evolved from a conservation focus to its current form of land and seascape units dedicated to sustainable development. The adoption in 1995 of the Seville Strategy and Statutory Framework of the World Network of Biosphere Reserves was a key milestone in this evolution as it reaffirmed biosphere reserves as internation�ally recognized sites with three interconnected goals: biodi�versity conservation; social, economic and cultural develop�ment of local communities; and learning on sustaining mutually beneficial relationships between conservation and development through research, monitoring, education and capacity-building. It also called for systematic adoption of a multi-stakeholder governance system, and the specific biosphere reserve zonation system comprised of a legally protected core area surrounded by buffer and transition zones, including resident communities. | Adapt-Mitig | 65 - 65 |
| UNESCO | Adapting to Change (2011) | In the exploration of the relationship between World Heritage forests and biosphere reserves, forest biosphere reserves can certainly bring useful experience, insights, tools and techniques in order to inter alia: • decrease ecological isolation through increased connec�tivity; • strengthen the contribution of local communities to forest conservation and sustainable management, linking forest conservation to climate change responses; and • improve generation, collection and sharing of relevant ecological and social knowledge, and best monitoring and management practices. | Adapt-Mitig | 65 - 65 |
| UNESCO | Adapting to Change (2011) | Giving incentives to local communities to plant trees, for example, payment through ecosystem services schemes, not only promotes ecological connectivity but also contributes towards climate change mitigation efforts by enhancing carbon storage and sequestration processes. | Adapt-Mitig | 67 - 67 |
| UNESCO | Adapting to Change (2011) | ii) Bia Biosphere Reserve (Ghana) Another example to promote ecological connectivity has recently been initiated in Ghana where communities bordering the Bia Biosphere Reserve are encouraged to sustainably use and manage wildlife resources within a defined area through the creation of biological corridors, referred to as community resource management areas (Attuquayefio and Fobil, 2005). In the long term, the idea is to create similar community managed corridors from the core area to other protected areas in the region, and also to other areas in Côte d'Ivoire. | Adapt-Mitig | 67 - 67 |
| UNESCO | Adapting to Change (2011) | Similar and other types of community involvement in forest management and governance have been initiated in biosphere reserves worldwide. Experiences, ranging from the Luki Biosphere Reserve in the Democratic Republic of the Congo (DRC) to Clayoquot Sound Biosphere Reserve in Canada and Maya Biosphere Reserve in Guatemala, have shown that the success of community involvement depends on many factors. However, they all concur that community participation at all levels of the management process – from planning, intervention to monitoring – and the respect for their traditional rights and social and cultural values are key to the success of joint management schemes (Kotwal et al., 2008). In the long term, the combination of scientific, local and indige�nous knowledge and practices, and the adaptive nature of community driven approaches to forest management greatly benefits the sustainability of forest ecosystems, while boosting economic returns and contributing to sustainable development on local and regional scales (Persha et al, 2011). | Adapt-Mitig | 67 - 67 |

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| UNESCO | Adapting to Change (2011) | iii) Forest Conservation and Climate Change With the intensified debates linking forest conservation to climate change resilience, forest biosphere reserves and World Heritage sites are expected to adopt strategies to address the challenges of climate change mitigation and adaptation, such as land use changes that integrate the conservation and sustainable use of forest resources with positive social and forest based livelihood outcomes. | Adapt-Mitig | 67 - 67 |
| UNESCO | Adapting to Change (2011) | Interesting opportunities in terms of new incentives to prevent deforestation and for sustainable forest manage�ment are offered by the REDD (Reducing Emissions from Deforestation and Forest Degradation) and REDD-plus financial mechanisms. In particular, REDD-plus not only includes traditional approaches to reduced deforestation and degradation, but also covers elements of conservation, sustainable forest management and enhancement of carbon sinks. Hence, the role of forest World Heritage sites and biosphere reserves, including sites with both designa�tions, as well as those with forested landscape linkages in their surroundings, assume special significance. Forest World Heritage sites and biosphere reserves could specifi�cally explore how the improved protection and sustainable management of forested landscapes within and around them could contribute towards improving the conservation of these sites while yielding benefits for a broad range of stakeholders, particularly the dependant local communi�ties. Although much remains to be defined in terms of eventual mechanisms for the implementation of REDD, especially the flow of benefits to communities and people directly involved in land use decision-making and forest related livelihoods, some biosphere reserve authorities are taking initiatives in line with developing climate change mitigation and adaptation options and income generation options for the sites and local communities. | Adapt-Mitig | 67 - 67 |
| UNESCO | Adapting to Change (2011) | Another component of this pilot project involves giving financial incentives to local communities to ensure the protection and natural regeneration of the savanna ecosystem in the area. The overall goal is to implement a sustainable development model around the Luki BR that will be integrated into the national REDD-plus strategy in order to decrease the rate of deforestation, as well as ensure the production of ecosystem goods and services to the local communities. | Adapt-Mitig | 68 - 68 |
| UNESCO | Adapting to Change (2011) | Together, World Heritage sites and biosphere reserves cover approximately 300 million hectares of forested land�scapes. As sites that are internationally recognized for their outstanding universal value and their contribution to multi-scale sustainability, they are expected to provide models for the protection of the world's forests while enhancing the vital ecosystem services they provide for human well-being. Sharing of knowledge, experiences and good practices within, between and outside these sites, combined with the search for and implementation of effective and innovative ways to enhance the benefits of separate and joint World Heritage–Biosphere Reserve designations in terms of biodiversity conservation and sustainable use, responses to climate change and commu�nities' well-being, should be seen as a priority in UNESCO's contribution to sustainable development from local to global levels. These endeavors should be guided by the recognition that people are an integral part of the bios�phere, and that the economic, social and cultural values they associate with biodiversity, including its forest compo�nents, will be critical in triggering the behavioral changes that are needed to allow for a more sustainable society for the benefit of present and future generations. | Adapt-Mitig | 68 - 68 |
| UNESCO | Adapting to Change (2011) | a National Park. The Polish part of the site was inscribed on the World Heritage List in 1979 while the Belarusian part was added in 1992. Due to huge differences in political systems, as well as nature conservation policies in both countries, each part is managed separately, however a joint management frame�work has been elaborated and accepted by the manage�ment authorities in both countries. Since the Belarusian part was added, there has been a major disparity in size and management between the two areas. The Polish part of the site consists almost exclusively of forest habitats, which have been subjected to a strict protection regime for over eight decades. This area is surrounded by a large forest complex, which in terms of management forms a complicated mosaic of patches of different protection regimes as well as productive forests. The World Heritage site (5,0 ha) also borders the forest lands added to the national park in 1996 (5,155 ha). Out of 53,000 ha managed by the State Forest Administration, 3,600 ha form Bial/ owiez. | Adapt-Mitig | 70 - 70 |
| UNESCO | Adapting to Change (2011) | a National Park's buffer zone. There are no separate regulations on the forestry practices within the buffer zone but hunting is forbidden there. Another 12,012 ha enjoy nature reserves status. Even though the reserves do not fall under a strict protection regime, timber exploitation is banned. Tree cutting is permitted only for safety reasons and the wood has to remain in the ecosystem. Hunting is also forbidden in the nature reserves. For each nature reserve, management plans should be prepared where detailed information on activi- 74 4 Adapting to Change – The State of Conservation of World Heritage Forests in 2011 Belovezhskaya Pushcha/Bial/ owiez. | Adapt-Mitig | 70 - 70 |
| UNESCO | Adapting to Change (2011) | a Forest 000 56 56<br>ties permitted must be elaborated. Activities permitted are planned in accordance to the main objective of the reserve. Reserves established for the protection of butterfly fauna or grassland habitats are managed in a different manner to those established for the old growth forests. | Adapt-Mitig | 70 - 71 |
| UNESCO | Adapting to Change (2011) | a Forest, the absence of timber exploitation throughout the centuries has ensured conti�nuity in terms of fluctuations of tree stand development processes. Individual trees are able to live until their natural death, reaching exceptional dimensions, unparalleled in other forest complexes of Europe. Within the strictly protected area, one can find exceptionally high amounts of dead trees, where strict conservation measures are in place. | Adapt-Mitig | 71 - 71 |

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| UNESCO | Adapting to Change (2011) | a Forest divided by the border fence into two herds. In the Polish part of the forest there are over 470 individuals and it is estimated that the existing mosaic of forest and non-forest habitats, as well as the proper management of the bison, can support such a population. It is clear that the long-term genetic viability of many Bial/ owiez. | Adapt-Mitig | 71 - 71 |
| UNESCO | Adapting to Change (2011) | Areas described by experts as ecological corridors are not currently protected as such in Poland. They may fall under different forms of protection if they form part of a protected area, such as a national park, nature reserve or landscape park. It is highly recommended though that ecological corridors, including watercourses, should be protected by national law. In 2005, the Polish Ecological Corridors Network was developed, financed by the Case Studies – On Connectivity 75 4 The Bial/ owiez. | Adapt-Mitig | 71 - 71 |
| UNESCO | Adapting to Change (2011) | a National Park was doubled when the area of 5,155 ha of managed forests was included in the park. The newly included forests are situated along the western and northern borders of the World Heritage site. The managers of these two areas, now joined under one national park, had to take into account that it was subjected to regular forest management practices, and the change of approach should be evolutionary. During the first years, the sanitary cuttings were continued and the amount of exploitation was based on the extent of bark beetle gradation. Starting from the year 2000, statis�tics show a reduction in the quantity of timber exploited due to a change of management approach. Today, the bark beetle is regarded as a natural element shaping ecosystems of the national park, therefore sanitary cuttings have dropped down to almost zero (Figure 2). | Adapt-Mitig | 73 - 73 |
| UNESCO | Adapting to Change (2011) | The area of strict protection in the national park now measures 6,061 ha. The remaining forest ecosystems (4,456 ha) of the park are partially protected, but the long-term management plan does not include timber exploitation in the area. As the connection of local communities, who have existed here for centuries, and the forest should be maintained, part of the area cannot be closed to people therefore it cannot fall under a strict protection regime. Visiting without a guide is permitted, as well as riding bicycles along marked trails, and picking berries and mushrooms. Meadows and grasslands, espe�cially those situated along the river valleys, are cut in order to maintain enough food for grazers, including the bison. As the entire Bial/ owiez. | Adapt-Mitig | 73 - 73 |
| UNESCO | Adapting to Change (2011) | a Forest is recognized under the Natura 2000 network, management of the area has to take into consideration the requirements of the European Habitat and Bird Directives. Hence, open habitats, shaped in the past by natural elements as well as human activities, should be maintained in order to support populations of species currently listed in the Annexes to European Union Directives, such as the lesser�spotted eagle and the corncrake. | Adapt-Mitig | 73 - 73 |
| UNESCO | Adapting to Change (2011) | a Forest is surrounded by a mosaic of natural landscapes, such as forests, peat bogs, meadows, pastures and arable land. There is no industry and the most urbanized area is the town of Hajnowka, inhabited by some 20,000 people. Management of the Case Studies – On Connectivity 77 4 Timber exploitation (m3 ) Year 5000 4500 4000 3500 3000 2500 2000 1500 500 0 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 Figure 2. Timber exploitation in the Hwoz. | Adapt-Mitig | 73 - 73 |
| UNESCO | Adapting to Change (2011) | na Protected Area Analyzing the amount of timber exploitation from the area added to the national park, one can observe the evolution in the management approach.<br>forest habitats administered by the State Forests varies depending on the status of particular fragments. Even though the nature reserves (12,012 ha) do not fall under a strict protection regime, timber exploitation and hunting is banned there. In the State Forests' part of the forest there are also numerous regulations, different to those in a typical production forest. Tree stands over 100 years old cannot be exploited, heavy machinery cannot be used, and an inventory of species has to be done before any activities can be undertaken. | Adapt-Mitig | 73 - 74 |
| UNESCO | Adapting to Change (2011) | Data show that 60 years ago spruce constituted over 25 per cent of the surface in the forest, in the 90s it was 16.6 per cent, while today it varies between 5–8 per cent. The surface percentage of oak remains at the same level at 19 per cent. Other species, such as lime and hornbeam, increase the surface percentage to 30 per cent. The fall in percentage of spruce is directly caused by more intensive and frequent gradations of bark beetle. However, it is necessary to bear in mind that bark beetle infestations are a secondary factor as bark beetles infest trees already weakened by other factors, such as long dry periods, strong winds that break or fell trees, high temperatures or a lowering of the groundwater table. These changes are recognized in the long-term management plan for the national park and regarded as existing and potential threats for existing ecosystems. Nevertheless, it is agreed that the main actions will involve monitoring of the processes and implementing practical measures, as much as possible, which allow the ecosystem to adapt to changes. Throughout its history, the forest has witnessed different climatic periods, but its very existence was never threatened. The main mission of the Bial/ owiez. | Adapt-Mitig | 74 - 74 |
| UNESCO | Adapting to Change (2011) | a National Park and the State Forest Administration was, 'Protection of Emys orbicularis (European pond turtle) and amphibians in the north European lowlands'. One of the goals of that project was creating breeding and feeding habitats for amphibians as well as their protection during spring migration between forest and grassland habitats. | Adapt-Mitig | 75 - 75 |

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| UNESCO | Adapting to Change (2011) | Within the area of the park as well as in the surrounding private lands there were new ponds created, supporting not only breeding populations of amphibians but also serving as water reservoirs for other animals and facili�tating migration of numerous species. Enhancing connec�tivity of ecosystems is also the aim of Protection of lesser�spotted eagle in Natura 2000 sites. The species nests in forest but feeds on grasslands and cut meadows – large scale meadow reclamation in the area of the Bial/ owiez. | Adapt-Mitig | 75 - 75 |
| UNESCO | Adapting to Change (2011) | a Forest had been protected in 1921. We would definitely have had the unique chance to observe natural processes on a much larger scale than today. It is also certain that some species currently living in the forest would have become extinct. The concept of nature protec�tion has changed over the twentieth century. Forest management practices and the perception of forest func�tions has also changed, though slowly. Knowledge on the functioning of ecosystems and some species' requirements has been much enhanced today. We should therefore use the experience gained as best we can so as to create a new formula for the Bial/ owiez. | Adapt-Mitig | 75 - 75 |
| UNESCO | Adapting to Change (2011) | It has been already observed that the non-productive functions of forests have a growing number of supporters, and there is even more support for protection. As a result, the protection regime of the Bial/ owiez. | Adapt-Mitig | 75 - 75 |
| UNESCO | Adapting to Change (2011) | a Forest often experiences conflict and heated debate over the form of management and protection that should be implemented. Moreover, the issue receives a great deal of international attention and various pressure due to its World Heritage status and to its European Diploma of Protected Areas designation. The management policy of the State Forest Administration was severely criti�cized over the past decades. Nevertheless, conflicts – if kept within healthy limits – can be constructive and this seems to have been the case in the Bial/ owiez. | Adapt-Mitig | 75 - 75 |
| UNESCO | Adapting to Change (2011) | In an effort to conserve these natural areas, countries in the region have made a considerable effort to remedy the situation and have established 526 protected areas inter�linked through a network of connected conservation corridors, known as the Mesoamerican Biological Corridor (MBC) – see figure 1. Since the early 1990s this initiative, originally known as Paseo Pantera (The Path of the Panther), received strong international support up until 2006. Today, many national efforts continue in addition to the second phase of the MBC Project announced by the Central American Commission of Environment and Development (CCAD) during the Convention on Biological Diversity (CBD) COP10 in Nagoya in 2010. | Adapt-Mitig | 76 - 76 |
| UNESCO | Adapting to Change (2011) | Sustainable development is achieved in biosphere reserves using an established system of governance that is partici�patory in its structure: land use planning is determined by a gradient of different uses, from core zones that are dedi�cated mainly to conservation, to buffer zones that are sustainably managed, and transition zones where human activity is greater and where benefits are shared with the local population. Local participation in conservation, devel�opment and research, and learning initiatives will allow for true empowerment of local communities. The biosphere reserve concept is well established and has gained impor�tance with several new nominations in recent years, but has to be strengthened and better enforced. Meanwhile, World Heritage sites offer a unique opportunity to show�case best management practices and increased manage�ment effectiveness and should serve as demonstration sites on how to achieve conservation within the national protected area systems. | Adapt-Mitig | 76 - 76 |
| UNESCO | Adapting to Change (2011) | Though these sites are faced with conservation challenges of their own, in relation to land use changes in the rest of the landscape in which they are located, they are rela�tively well conserved. As such, they are well positioned to play a key role as conservation nodes at the regional level. | Adapt-Mitig | 76 - 76 |
| UNESCO | Adapting to Change (2011) | Conclusion Conserving the biodiversity and forests in the region requires the strengthening of institutions, the develop�ment of well targeted and enabling land use policies, the promotion of inter-sector cooperation, and the empow�ering of local communities, mainly through education and by increasing their communication and access to informa�tion. While mitigation strategies are globally driven and the carbon markets are being handled by a diverse set of organizations, adaptation strategies will have to be developed locally. This implies that research and informa�tion networks have to be established, while the meteo�rological network must be strengthened. Local people and professionals must be trained to use information for deci�sion-making. Local knowledge must be incorporated into knowledge systems. | Adapt-Mitig | 80 - 80 |
| UNESCO | Adapting to Change (2011) | The use of protected areas as natural solutions to both mitigation and adaptation will be vital (Dudley et al., 2010). Results from surveys conducted in the 1990s indicate that 80 per cent of the forest cover remained in protected areas, while only 31 per cent remained outside of these areas (Sader et al., 2001). Current efforts by the CCAD (Comision Centroamericana de Ambiente y 84 4 Adapting to Change – The State of Conservation of World Heritage Forests in 2011 Source: FAO (2011) State of the World's Forests 2011. | Adapt-Mitig | 80 - 80 |

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| UNESCO | Adapting to Change (2011) | Of the mechanisms and designations mentioned above, only World Heritage sites enjoy systematic monitoring on the state of conservation on behalf of the global commu�nity through the World Heritage Committee. The Committee, in this capacity, has a unique role to play in dialoguing with national governments to encourage the adoption of necessary measures designed to guarantee the long-term conservation of World Heritage sites. In many cases, the World Heritage Committee has requested that governments take action in matters well outside the boundaries of the World Heritage site in order to better ensure the site's conservation. In light of such precedents, it is not unreasonable to consider the role the World Heritage Committee can play in encour�aging governments to pay more attention to connectivity issues, and to implement measures such as those mentioned above, not only as good management prac�tices, but also as a strategy to adapt to climate change. | Adapt-Mitig | 81 - 81 |
| UNESCO | Adapting to Change (2011) | Case Studies – On Connectivity 85 4<br>Introduction The principle of World Heritage is based on the recogni�tion of outstanding universal value granted to a cultural or natural site with an emphasis on the conservation and manifestations of this value. Through the years, the partic�ipation of local stakeholders in matters of conservation has been recognized as essential in achieving success. In this regard, the concept of the biosphere reserve leads the way in seeing beyond the nature reserve as hunting grounds of fauna once used by colonialists through the involvement of local populations. However, despite the institutional attempts to reach a balance between conservation and development, forest related conflicts still persist, particu�larly between the managers of protected areas and resi�dent populations. Several attempts to settle these conflicts have been put in place, but tensions remain and have yet to be resolved. | Adapt-Mitig | 81 - 82 |
| UNESCO | Adapting to Change (2011) | After a decade of harmonizing forestry policies in the countries adjoining the Congo Basin, the decentralization of natural resources management remains an important issue for in situ biodiversity conservation strategies world�wide. This importance demonstrates the central role played by local stakeholders in biodiversity governance strategies, while taking into consideration their interests and diversity. Environmental governance, conceived as a framework for multi-stakeholder dialogue and resource management, distinguishes itself from the ideology of social exclusion. Consequently, Model Forests 3 act within the processes of conflict resolution so as to facilitate community dialogue. As well as linking poverty and devel�opment issues, Model Forests also offer a framework of innovation, the promotion of local entrepreneurship, and experimentation on alternative projects of natural resource management. Model Forests also work towards a process that leads to 'standing on their own two feet' by inno�vating in terms of environmental governance and the improvement of living conditions for local populations. | Adapt-Mitig | 82 - 82 |
| UNESCO | Adapting to Change (2011) | On April 28, 2008, Decision No. 0330D/MINFOF/SG/DFAP was taken regarding the management structure of the Dja Faunal Reserve. The text defined its organizational structure consisting of a new managerial framework comprising a Management Committee (MC), a Consultative Committee (CC), a Scientific and Technical Committee (STC), and a Conservation Service (CS), which is the operational arm consisting of forestry stations and communication satellites within the DFR. Given the diverse stakeholders involved, as well as the application of the management's measures, the DFR's vision and objectives evolved such that today, the protected area is considered as a natural and social environment that favours the emergence of frameworks of cooperation and dialogue between the various stakeholder groups. | Adapt-Mitig | 82 - 82 |
| UNESCO | Adapting to Change (2011) | 86 4 Adapting to Change – The State of Conservation of World Heritage Forests in 2011 Multi-actor Partnership and Sustainability Management of Biodiversity: The Case of the World Heritage Site of the Dja Faunal Reserve (DFR) by Gustave Ossie Ompene, Patrice André PA'AH1, Théophile Bouki 2, Jean-Claude Stone Njomkap 2, Julie Gagoe Tchoko 2 and Mariteuw Chimère Diaw2 1. Respectively, Focal Point and Executive Secretary of the Model Forest of Dja and Mpomo (FOMOD) 2. Secretariat of the African Model Forests Network (AMFN) 3. The concept of Model Forest was conceived in Canada in the 1990s and was adopted by the government of Cameroon in 2005, and is described as a 'partnership aimed at accelerating the application of sustainable development by systematically taking into consideration the interests of every stakeholder...'<br>This paper attempts to demonstrate the different positions held in terms of sustainable management by the DFR, and how they integrate dialogue in the FOMOD, and how, in return, local, private, public and community stakeholders could be encouraged to contribute towards the ecological integrity of the DFR. These conditions are essential to the dynamic of local development. | Adapt-Mitig | 82 - 83 |
| UNESCO | Adapting to Change (2011) | History of the occupation of DFR by local populations and the new management approach to fauna For several centuries the DFR has been occupied by the Ndjemé, Nzimé, Badjoué, Baka, Bulu, and Fang ethnic groups (Tchikangwa, 1996). These populations lived in the forest environment as hunter-gatherers, and used their surroundings for agriculture and cultural rites. Visible traces of their occupation can be seen in the abandoned cocoa and coffee plantations in ancient forests, by the dikes crossing certain swamps, the sanctuaries, and inci�sion marks left on trees from tapping rubber (Oyono, Diaw and Efoua, 2000). These subsistence practices have never posed a threat to biodiversity and no species has ever been at the brink of extinction as a result, despite the fact that the diet of these populations was essentially based on meat and fish (Madzou, 2008). Consequently, several studies have shown that native populations have ethno�scientific knowledge of plants and therefore were able to benefit from their dietary, therapeutic or mechanical virtues, as well as exploit animal resources, with a principal focus on big mammals (Dounias, 1999; Oyono, 2002). | Adapt-Mitig | 83 - 83 |

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| UNESCO | Adapting to Change (2011) | Not only does this contribute to the degradation of the environment but it also leads to conflicts over uses. These factors have contributed in creating groups of stake�holders with divergent interests around the reserve. Thus management decisions in the DFR remain potentially contentious with regard to approaches that seek to valorize natural resources as well as financial returns on activities led by certain investors. The confrontation of these different interests has immediate consequences on the area such as the escalation of illegal activities, namely poaching and illegal exploitation of the forest. | Adapt-Mitig | 83 - 83 |
| UNESCO | Adapting to Change (2011) | Faced with the real threats to the sustainable management of the DFR, several actions were carried out by the Ministry of Forest and Fauna (MINFOF) so as to reinforce its control, but also to spurr anti-poaching campaigns with the help of partnerships established between the different Model Forest stakeholders. A consultative framework set up at the local level soon became a platform for dialogue between the many partners. Examples include: • Partnerships forged between forestry and mine devel�opers and the local population, represented by their local forestry committees, through local consultative committees. | Adapt-Mitig | 83 - 83 |
| UNESCO | Adapting to Change (2011) | Protection and management of natural and cultural heritage This coincides with the mission of the World Heritage site with respect to Dja's exceptional heritage and its natural areas and biodiversity. In common with the DFR, the FOMOD, is watchful over the long-term protection and management of the environment, particularly the more fragile and vulnerable environments such as wetlands, agricultural areas in transition, forest lands, flood areas, mountain ranges with little fragmentation, flooded wood�lands, forests in ravines, and biodiversity corridors. The DFR must also guarantee the dynamic conservation of landscapes and sites identified as remarkable and/or fragile. In this context, the Model Forest partnership has a serious responsibility to both protect and valorize the area's natural heritage. | Adapt-Mitig | 84 - 84 |
| UNESCO | Adapting to Change (2011) | Experimentation The FOMOD mobilizes stakeholders, techniques, and legal and statutory capacities to experiment and develop new solutions that are capable of contributing towards the different objectives defined by the DFR. Moreover, it contributes towards identifying research topics and towards facilitating the implementation of research or R&D programmes that could be transferred to other Model Forests within the framework of knowledge management; a system of sharing knowledge. This repre�sents a major sub-regional point of reference for issues related to the application of sustainable development in protected areas. | Adapt-Mitig | 84 - 84 |
| UNESCO | Adapting to Change (2011) | Building linkages to support environmental governance: the necessity of an institutional consultative framework In its strategy of promotion and support of decentraliza�tion for good forestry governance, the Dja and Mpomo Model Forest aims to reinforce its consultative framework so that it is acknowledged in the field of multi-stakeholder management. This would require cooperation from all stakeholders having activities in and around the DFR. | Adapt-Mitig | 84 - 84 |
| UNESCO | Adapting to Change (2011) | Accords between operational partners would encourage the emergence of local governance that allows for the sustainable management and integrated development of the physical and social environment, as well as the applica�tion of 'good practices' in forest planning without chal�lenging the rights and obligations of partners. An analysis of ongoing projects reveals that a real dynamic of change could be developed based on the multiple exchanges 88 4 Adapting to Change – The State of Conservation of World Heritage Forests in 2011<br>between institutional stakeholders. Currently, this involves providing feedback to those initiatives developed by the different partners so as to enable each actor to respond to a number of key issues raised through close collaboration, shared learning, and innovation. | Adapt-Mitig | 84 - 85 |
| UNESCO | Adapting to Change (2011) | Furthermore, conflicts are an integral part of the social game whose objectives are constantly changing. The ques�tion is whether the 'Model Forest partnership' is sufficient to reassure stakeholders, individuals or institutions that have difficulties in recognizing the value of working together. Unfortunately, this is fairly common and the reason why they should be consistently reassured of the good working and organizational conditions, which facili�tates open democracy, including freedom of expression, internal discussion, and conviviality. The institutionalization of co-management and the capacity-building of FOMOD's groups of stakeholders are open opportunities to reinforce consultation and partnerships that seek social compro�mise. In this vein, FOMOD plans to mobilize resources to create an information centre on social forestry with head�quarters located in Lomié. This centre will help create a database that benefits and documents local skills and scientific knowledge on all the local resources, including biodiversity management inside and outside the DFR. Such an initiative would have environmental benefits and ease tensions and prevent conflicts. Thus, projects leaders working for example on medicinal plants and traditional pharmaceutics, will better perceive the benefits of dialogue and cooperation with others. | Adapt-Mitig | 85 - 85 |
| UNESCO | Adapting to Change (2011) | In forest co-management, the creation of linkages between stakeholders minimizes the time and energy spent on conflicts and therefore attention can easily be directed towards establishing participative actions on envi�ronmental management. The FOMOD has identified ways to reconcile biodiversity conservation and the multi-uses of the environment for the purpose of sustainable develop�ment. Within this framework, farmers whose practices are based on constructive collaborative action will be better aware of the relationship between the needs for local development and environmental issues. The challenge for FOMOD is to reconcile environmental conservation with promoting local development within the context of ever�changing rural societies. | Adapt-Mitig | 85 - 85 |
| UNESCO | Adapting to Change (2011) | Relying on an evolving legal framework, particularly decentralized taxation, the partnership seeks to develop local mechanisms of distribution and benefit-sharing from forest management for the population. It intends to encourage harmonization and awareness raising among all the stakeholders concerned with biodiversity conserva�tion issues within the World Heritage site and its borders. | Adapt-Mitig | 85 - 85 |

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| UNESCO | Adapting to Change (2011) | The FOMOD actively works towards synergy in its actions  in order to provide every stakeholder with an opportunity  to find solutions to their own problems, and to achieve its  objectives while reconciling environmental conservation  and the development of economic activities. Benefits to  the environment will only be effective if there are mutual  advantages, for example, a FOMOD project is producing  high quality pens using wood residues from community  forests. Although this is still in its experimental phase,  particularly its transformation into an equitable and  Case Studies – On Connectivity   89  4 sustainable business, this project demonstrates the feasi�bility of a FOMOD economic and environmental project in  the eyes of the stakeholders. Reaching a social compro�mise in terms of mutual benefits requires the creation of a  framework of broad consultation and dialogue among all  stakeholders and at all levels – from indigenous people  and farmer communities through to forest administrations,  forestry and mine developers, rural elites, and so on. | Adapt-Mitig | 85 - 86 |
| UNESCO | Adapting to Change (2011) | Conclusion   An adage known to all inhabitants of the Dja river says, 'In  a group of fishermen aboard the same boat, each member  is personally responsible for the safety of all because, in  case of shipwreck, even the best swimmer will get wet  before reaching the shore.' This adage suggests that the  development of partnerships for biodiversity conservation  in the DFR calls on the participation of all stakeholders. | Adapt-Mitig | 86 - 86 |
| UNESCO | Adapting to Change (2011) | Since the implementation of the Cameroon Model Forest  process, the DFR management has evolved in line with  the spirit of the great names of contemporary environ�mental governance, from the Brundtland report (1987)  and the Rio conference (1989), to the Cameroon and  Congo Basin forestry decentralizations established since  the mid 1990s. Within this political and conceptual space,  Model Forests have positioned themselves as a forum for  the development and application of sustainable develop�ment at various local, regional and global scales. | Adapt-Mitig | 86 - 86 |
| UNESCO | Adapting to Change (2011) | Cameroon joined this movement in the mid 2000s and  has made real progress to date. However, as highlighted  by several authors, for example, Dounias (1999), recon�ciling the needs of conservation and the necessity for  productive human development remains an extremely  complex task. Achieving success in this process remains a  pivotal issue for FOMOD and the DFR, whose manage�ment aspires to environmental conservation and the equi�table distribution of benefits. | Adapt-Mitig | 86 - 86 |
| UNESCO | Adapting to Change (2011) | Within this context, the largest tropical dry forest of South  America, the Chiquitano Dry Forest, originally distributed  over Bolivia, Brazil and Paraguay (Figure 1(a)), and declared  a Model Forest by the International Model Forests  Network, maintains good ecological integrity and func�tionality levels. This is due in large part to slow-moving  socioeconomic and demographic development in eastern  Bolivia – its principal geographic distribution area  (Dinerstein et al., 1995; Ibisch et al., 2003) – but also to an  important network of protected areas and existing forest  concessions across its entirety (Vides-Almonacid, Reichle  and Padilla, 2007). Today there are more than 15 million  hectares of almost continuous forest coverage, consti�tuting an opportunity to design and implement integral  ecosystem management strategies that, through the  sustainable use of wood resources, non-wood resources  and key environmental services, such as water and carbon  stock maintenance, allows for the establishment of a base  for its management and conservation. | Adapt-Mitig | 87 - 87 |
| UNESCO | Adapting to Change (2011) | The Chiquitano Dry Forest links more than 11.8 million  hectares of parks and reserves of different categories   and jurisdictions, some of great value for humanity. Among  these, the Noel Kempff Mercado National Park (with  1.5 million ha), declared a natural World Heritage site, as  well as Ramsar sites such as the Bolivian Pantanal and  Concepcion, Kaa-Iya del Gran Chaco National Park (one of  the largest parks in South America with 3.3 million ha),  Otuquis National Park, San Matías ANMI (Natural Area of  Integrated Management), Tucavaca Valley Reserve, Ríos  Blanco y Negro Wildlife Reserve, among various others   of national, regional and local importance (Figure 1(a)). | Adapt-Mitig | 87 - 87 |
| UNESCO | Adapting to Change (2011) | Case Studies – On Connectivity   91  4  Ecological Integrity and Sustainable Development  in the Chiquitano Dry Forest, Bolivia  by Roberto Vides-Almonacid and Hermes Justiniano  Chiquitano Forest Conservation Foundation (Fundación para la Conservación del Bosque Chiquitano) This is in addition to the more than twenty-two forest  concessions, amounting to almost 2.2 million ha, of  which eight (868,000 ha) are certified under the Forest Stewardship Council (FSC), as well as twelve community  lands (more than 6 million ha) of the Baure, Chiquitana,  Ayoreode and Guarani communities, and a significant  number of small private reserves and other local forest  concessions (Figure 1(a)). This extensive and heteroge�neous mosaic of land use rights, superimposed in many  cases, confers a complex panorama in terms of gover�nance. But at the same time it also provides an opportu�nity-filled setting for counteracting deforestation trends,  encouraging connectivity between large areas of  protected forests, and promoting the conservation and  sustainable use of biodiversity. | Adapt-Mitig | 87 - 88 |
| UNESCO | Adapting to Change (2011) | Land management strategies  In view of this assortment of threats and opportunities, a  series of land and natural resource management strategies  can be added to the pile, which – when adequately formu�lated and implemented – could contribute to maintaining  the ecological integrity of the Chiquitano Dry Forest in the  long term. Land-use planning has different geographic  and jurisdiction scales on the one hand, but on the other,  the policies applied to the use of natural resources and access rights generate a basis of technical, socioeconomic  and political criteria for the appropriate use of land, and  the planned occupation of the area. | Adapt-Mitig | 88 - 88 |

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| UNESCO | Adapting to Change (2011) | In the land use planning process, four instruments, corre�sponding to the different scales, must be represented: the Departmental Land Use Plans (in this case, of the depart�ment of Santa Cruz, Bolivia, where the majority of the Chiquitano Dry Forest is located), the Municipal Land Use Plans (PMOT – protected by the New Political Constitution of the Bolivian State), the Indigenous Land Management Plans (applied to native and peasant community lands), and the Land Use Plans (applied to private farms). Each one of these instruments constitutes management oppor�tunities that could promote connectivity on multiple scales, as well as the protection of sites – key for the func�tioning of ecosystem services such as water, the conserva�tion of biodiversity (establishing protected areas), and for the identification of areas of forest susceptible to defor�estation or degradation on which mechanisms like REDD+ could be applied. The PMOT design for the Chiquitana 92 4 Adapting to Change – The State of Conservation of World Heritage Forests in 2011 Figure 1. Chiquitano Dry Forest Ecoregion Figure 1(a) shows the different usage rights in the Chiquitano Dry Forest Ecoregion; Figure 1(b) the distribution of three non-wood forest products and Figure 1(c) indications of the design stage of municipal land-use plans in several municipalities of the Chiquitano region. | Adapt-Mitig | 88 - 88 |
| UNESCO | Adapting to Change (2011) | For its part, the use of forest resources, under regulations currently in force in Bolivia, allows for large areas of the Chiquitano forest to be kept in good health, especially if they are found to be under voluntary certification mecha�nisms, creating a source of connectivity and ecological integrity opportunities. The use – still incipient – of valu�able non-wood forest resources, such as the Chiquitana almond (Dipteryx alata), cusi palm (Attalea speciosa) or copaibo oil (Coppaifera spp.), also creates a promising option for establishing extensive protection areas for its long term management. Recently, one of the municipali�ties of the Chiquitano Dry Forest created a new protected area (347,000 ha), stemming from the interest in main�taining and managing the natural forest under a non�wood products exploitation scheme, in this case, for the extraction of copaibo oil (Figure 1(a) and (b)). | Adapt-Mitig | 89 - 89 |
| UNESCO | Adapting to Change (2011) | The existence of protected areas of differing classes, and the opportunity to create new ones on local scales, within the framework of the application of Ecosystem Approach principles, in particular of decentralization and decision�making at the lowest possible level, completes the mosaic of conservation schemes contributing to connectivity and integrity. The establishment of a departmental system for Santa Cruz of protected areas, which seeks to coordinate between national, regional and local levels, can produce excellent results as long as a legal normative framework and the political will exist to make it effective opera�tionally. Without a doubt, achieving this coordination will be crucial in ensuring connectivity and integrity, not only for the forest, but also between the linked ecoregions (Chaco, Pantanal, Amazon), as well as a climate change adaptation strategy based on healthy ecosystems. | Adapt-Mitig | 89 - 89 |
| UNESCO | Adapting to Change (2011) | Socio-ecological resilience and management models The Chiquitano Dry Forest was incorporated into the International Model Forests Network in 2005. As a Model Forest, it seeks to generate agreements between key actors to develop land and natural resource management, sustainable agricultural production, biodiversity conserva�tion, and the promotion of scientific and traditional knowl�edge. Despite successive planning efforts on the ecoregion scale (Ibisch, Columba and Reichle, 2002; Vides�Almonacid, Reichle and Padilla, 2007; FCBC, 2010), the governing structure, allowing for the coordination of strategies between different governmental levels and which is agreed on by all sectors involved, is still weak. The application of Ecosystem Approach principles, as a strategy developed by the Convention on Biological Diversity, continues to present a big challenge for meeting the Model Forest objectives in the Chiquitano Dry Forest. | Adapt-Mitig | 89 - 89 |
| UNESCO | Adapting to Change (2011) | However, the need to ensure the socio-ecological resilience of this tropical forest is becoming increasingly obvious, in view of not only climate changes but also political, economic and cultural changes which are felt ever more forcefully in the region. The participation of local actors, the creation of capacities, and the boost in land management and natural resource capabilities, as a step towards the establishment of collaborative approaches and planning for future development options, constitutes the main path towards maintaining the ecosystem services at landscape level (McAfee et al., 2010). Furthermore, given that biodiversity increases the resilience and resistance of forest ecosystems that are facing the changes, its conservation should be a core element of any management model applied to the terrain (Thompson et al., 2009). | Adapt-Mitig | 89 - 89 |
| UNESCO | Adapting to Change (2011) | Case Studies – On Connectivity 93 4 Serrania de Santiago © Hermes Justiniano<br>The complex mosaic of usage rights in the Chiquitano Dry Forest region (as shown in Figure 1), provides a platform from which initiatives like REDD+ can be developed, as well as other actions that strengthen conservation and natural forest management units. With this in mind, it becomes necessary to: • Consolidate existing protected areas (national as well as regional and local), through effective administration, providing them with legal security and sufficient staff, and adequately preparing and equipping them with realistic and viable management plans. | Adapt-Mitig | 89 - 90 |
| UNESCO | Adapting to Change (2011) | • Integrate new sustainable forest management approaches – driven by the national government of Bolivia, in which greater control is given to local commu�nities with reference to the business efforts in the region – while searching to increase voluntary forest certification mechanisms that contribute to a fairer distribution of the economic benefits resulting from forest exploitation. | Adapt-Mitig | 90 - 90 |
| UNESCO | Adapting to Change (2011) | • Boost the management of non-wood resources as an alternative and/or complement to the use of native tree species, which socially and economically justifies the maintenance of large areas of forest, as is the case in the Copaibo Reserve (Figure 1(a), orange polygon to the north). | Adapt-Mitig | 90 - 90 |

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| UNESCO | Adapting to Change (2011) | • Promote the implementation of existing instruments for planning and land management, on regional, municipal, indigenous and private scales, as a valid and technically supported strategy for land use and territorial occupa�tion, which considers and strengthens connectivity options either through maintaining environmental ease�ment or by boosting protected forests, private reserves or new local area (municipal or community) networks. | Adapt-Mitig | 90 - 90 |
| UNESCO | Adapting to Change (2011) | • Establish an effective governance platform between actors and sectors directly involved in the land manage�ment of the Chiquitano Dry Forest and management of its natural resources within the framework of the Model Forest management model, using the applica�tion of the Ecosystem Approach principles as a guide to its development. | Adapt-Mitig | 90 - 90 |
| UNESCO | Adapting to Change (2011) | 94 4 Adapting to Change – The State of Conservation of World Heritage Forests in 2011 Tabebuia trees flowering © Hermes Justiniano<br>Concluding remarks In this context, adaptive management as 'active learning' is established as a real paradigm for creating an effective and creative management model against the backdrop of global changes in the Chiquitano Dry Forest. Thus, we must learn more about REDD+ mechanisms on a sub�national scale (in the sense of Angelsen et al., 2008), the coordination of sustainable exploitation models for wood and non-wood resources, the implementation of land-use planning on multiple scales, the effective management of protected areas, and the monitoring of biodiversity as they will be determining factors in maintaining large areas of protected forests, connecting wildlife corridors, and the provision of products and ecosystem services to society. | Adapt-Mitig | 90 - 91 |
| UNESCO | Adapting to Change (2011) | In this sense, the Chiquitano Dry Forest provides an ecore�gional platform where approaches and ecosystem management models are put to the test, given the context of growing difficulties and threats that require rapid and effective learning and adaptation. | Adapt-Mitig | 91 - 91 |
| UNESCO | Adapting to Change (2011) | Considering World Heritage sites – and taking into account the Noel Kempff Mercado National Park in partic�ular – the need to significantly improve the coordination of governance levels and decision-making becomes clear, as does the need to capitalize on lessons learnt and promote new management models. Presently, under the exclusive responsibility of the National State, there are deficiencies in regional (departmental) and local (municipal) govern�ment participation and from other civil society organiza�tions necessary for its management and conservation. A few years ago, the shared (public-private) administration management model for the national park allowed a reasonable balance between investments and manage�ment results, for which new contexts of consent and participation should be sought within the framework of the Model Forest or other plural authorities with UNESCO involvement. In this way, a World Heritage site and a Climate Action Project area could be preserved in perpe�tuity as a reference for REDD+ initiatives and as an example of integration on the different geographic and jurisdiction scales. | Adapt-Mitig | 91 - 91 |
| UNESCO | Adapting to Change (2011) | World Heritage Forest meeting, Berastagi (1998) This compilation was developed during the 1998 Berastagi meeting (Indonesia) in 1998 that concentrated exclusively on tropical forests with a potential for inscrip�tion onto the World Heritage List. The concluding state�ment acknowledged that tropical forests were already fairly well represented on the List. However, gaps could still be identified and the Convention should therefore aim for a truly representative 'network' of tropical forests under World Heritage protection. Participants not only suggested potential new forest sites but also recom�mended that the World Heritage Centre prioritize the management of existing sites, hence ensuring the mainte�nance of their Outstanding Universal Value. | Adapt-Mitig | 106 - 106 |
| UNESCO | Adapting to Change (2011) | Expert Meeting on Boreal Forests, St.Petersburg (2003) In 2003, an expert meeting was held in St. Petersburg (Russian Federation) with the objective of identifying boreal forests with the potential for inscription onto the World Heritage List. This initiative mainly involved four countries: Canada, Finland, Norway and Russia. The expert group highlighted the great threat boreal ecosystems faced due to industrial activities and climate change, and reminded the international community of the great urgency concerning their protection. The panel made several recommendations to the World Heritage Centre, States Parties, site managers and IUCN, and identified a list of twelve potential new sites, five proposals for expan�sions, and seven sites warranting further evaluation. | Adapt-Mitig | 106 - 106 |
| UNESCO | Adapting to Change (2011) | When World Heritage forest sites coincide with Ramsar sites or Biosphere Reserves, there may be opportunities to leverage additional support for conservation efforts by tapping into either the constituencies of the corresponding Convention or programme, or by strengthening an argu�ment for conservation measures under consideration. To this end, providing a ready list of World Heritage forest sites that coincide with Ramsar sites and/or Biosphere Reserves can serve as a tool to facilitate the work of World Heritage forest conservation stakeholders. | Adapt-Mitig | 107 - 107 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Factoring climate change into management of the World Heritage properties has many other benefits. Conservation of heritage will also increase the resilience of human communities to the impacts of climate change, for example through ecosystem services that World Heritage sites provide. Many World Heritage sites serve as natural buffers against climatic impacts and other disasters, or play a major role in climate change mitigation by reducing climate-altering carbon dioxide emissions in the atmosphere. | Adapt-MitigImpacts | 5 - 5 |

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| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | The World Heritage Centre has since endeavoured to provide support to States Parties and site managers in tackling climate change threats, for example through field projects in Peru (Manú National Park) and Indonesia (Tropical Rainforest Heritage of Sumatra), as well as the publication of Climate Change and World Heritage – Report on predicting and managing impacts of climate change on World Heritage and Strategy to assist States Parties to implement appropriate management responses,1 the Policy Document on the Impacts of Climate Change on World Heritage Properties, 2 and the compendium of Case Studies on Climate Change and World Heritage.3 This Practical Guide is an additional output from the World Heritage Convention's secretariat. We hope that it will be a good resource tool for World Heritage site managers interested in understanding how to respond to climate change, along with the climate change publications mentioned above. | Adapt-MitigImpacts | 6 - 6 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | A key challenge in producing this guide was to define its scope – many of the suggested activities may not be obviously linked to climate change, and it is for the manager to make those links where appropriate. However most, if not all, protected area and natural resource management challenges can be linked to climatic factors. For example, conflicts over natural resources such as land, food, shelter and water can usually be linked to stresses caused by drought, flooding, erosion or disease, which are generally climate-driven. Therefore we have interpreted climate change adaptation in this guide quite broadly. | Adapt-MitigImpacts | 9 - 9 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | A logical approach While management planning is not necessarily a chronological process, it is important to work systematically, first by trying to understand likely future climate change scenarios and by understanding how the OUV of a site might be affected by such conditions – this will depend on assessing vulnerability of the features that contribute to its OUV, linked to the implications of a range of climate scenarios. Some features may be more vulnerable to certain climate change impacts than others. | Adapt-MitigImpacts | 10 - 10 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Weathering Uncertainty: Traditional Knowledge for Climate Change Assessment and Adaptation. Paris/ Darwin, UNESCO/UNU. http://unesdoc.unesco.org/images/0021/002166/216613e.pdf 15 Using the guide 1.6 A note on gender Women are disproportionately affected by climate change impacts, such as droughts, floods and other extreme weather events, because of women's limited access to resources, restricted rights, limited mobility and lack of voice in decision-making. However, women also play an important role in supporting households and communities to mitigate and adapt to climate change. | Adapt-MitigImpacts | 13 - 14 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | When designing adaptation strategies, it is crucial that climate change responses are gender aware, ensuring that women and men have an equal voice in decision-making on climate change and equal access to the resources necessary to respond to its negative effects. | Adapt-MitigImpacts | 14 - 14 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | In 2007 the IPCC presented its Fourth Assessment Report.8 The report confirms that climate change is occurring now, mostly as a result of human activities (Figure 1). It illustrates the impacts of global warming already under way and to be expected in future, and describes the potential for adaptation of society to reduce its vulnerability. It also presents an analysis of costs, policies and technologies intended to limit the extent of future changes in the climate system. Some of this information has already been summarized in the previous climate change publications of the World Heritage Centre (see preface). The IPCC Fifth Assessment report will be completed in 2014. | Adapt-MitigImpacts | 17 - 17 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | http://cognexus.org/wpf/wickedproblems.pdf 1) The traditional approach – identify the problem and then seek the solution – does not apply. Trying to understand the problem and then arriving at the solution may be impossible because different groups may see problems and solutions in different ways, and because there may be many unanticipated side effects resulting from different solutions. It is vital that in considering solutions, the natural World Heritage site manager critically analyses the possible ecosystem responses. 20 2 Understanding the context 2) There is no stopping point. All solutions are 'interim', and are driven by limits on political commitment, money, current understanding, human resources, time and energy. Managers must continually monitor the implications to their management interventions so that they can further improve or adapt them to changing environmental, social, economic or political realities. | Adapt-MitigImpacts | 17 - 18 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | 5) Many solutions risk being expensive trials by error. All attempts at management on the ecosystem scale are expensive, complex and prone to some degree of failure, and it may be impossible to go back and try again, because the underlying conditions such as temperature or precipitation patterns are also changing. | Adapt-MitigImpacts | 18 - 18 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | The capacity of World Heritage site management to adapt to climate change is determined by a number of activities taking place in the surrounding landscape. All protected areas have a spatial relationship with their surroundings, and exist within their wider ecosystems. A range of activities and requirements beyond the site will have a profound impact on its viability. Therefore, successful adaptation depends on the capacity of site managers to reconcile these different demands. | Adapt-MitigImpacts | 19 - 19 |

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| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | A consistent approach to documenting, recording and reporting the attributes of your site's key features will provide the basis for future impact assessment, as well as the basis for designing and implementing adaptation strategies. | Adapt-MitigImpacts | 27 - 27 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Extent and distribution of each species Reproduction rates and processes Grazers/browsers – species and distribution Presence of competing vascular species – rates of encroachment and loss Precipitation, temperature Site feature 9 Attributes (for each endemic landbird) Cloudey Island petrel Population size – numbers of pairs – dispersal Breeding sites – location, number Breeding rates – how often, how many Predation rates – native and non-native predators Competitors – native and non-native competitors Death rates – ageing, accidental death, exposure to disease Frequency of storm events/wind conditions Temperature, precipitation Feeding – locations, food species, habitats The above attributes should be monitored because they provide the basis for evidence of any changes that may be linked to climate factors, and therefore how the OUV might be negatively impacted. The managing team needs to consider how to consistently measure these attributes and how to present the results, in order to assess the condition of each feature and whether it is declining, stable or improving. The Operational Guidelines recommend site managers to identify 'key indicators for measuring its state of conservation'. | Adapt-MitigImpacts | 29 - 29 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Worksheet 3: Features and attributes – objectives Features Attributes Objectives FEATURE A B C D FEATURE A B C D FEATURE A B C D<br>33 Planning for adaptation 3 3.3 Assess your site (3) – understand its sensitivity and vulnerability It is important to remember that your site may contribute significantly to mitigating the effects of climate change – tropical forests, salt marshes and mangroves, sea grasses and peat uplands store large quantities of carbon, and most of them also serve as refuges and pockets of biodiversity that retain metapopulations, and in some cases act as natural protective barriers to climate-related physical impacts and other effects such as diseases. Moreover, as World Heritage sites are usually the largest, and often among the best�conserved within a local or regional network of protected areas, they can act as a centre of species dispersal to smaller protected areas, contributing to biodiversity conservation throughout a broader landscape. In this way, your site can play an important climate change adaptation role for the larger protected areas network. | Adapt-MitigImpacts | 30 - 31 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Protected areas also serve as natural buffers against climate impacts and other disasters, providing space for floodwaters to disperse, stabilizing soil against landslides and blocking storm surges. It has been estimated that coastal wetlands in the United States provide US$23.2 billion a year in protection against flooding from hurricanes. | Adapt-MitigImpacts | 31 - 31 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Natural Solutions: Protected areas helping people cope with climate change (Dudley et al., 2010) Outstanding Universal Value Sensitivity, Vulnerability, Resilience Features and attributes Capacity to adapt Context – World Heritage, climate change Climate change scenarios Potential options Assessing risk Implementation logistics Prioritizing action Monitoring and evaluation Emerald Lake, Canadian Rocky Mountain Parks (Canada). © Maureen Flynn<br>34 3 Planning for adaptation boundaries may be too porous to maintain integrity in the face of encroachments of many kinds – extraction, pollution, settlements, poaching and so on. A site may be particularly sensitive if it is a rare or unique type of habitat, or if it is isolated from similar sites. In Section 3.4 we ask 'how resilient is your site?' A sensitive site may be the opposite of a resilient site, as demonstrated by the examples given. | Adapt-MitigImpacts | 31 - 32 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Lack of corridors and buffer zones results in the inability of species to migrate and find new breeding and feeding grounds, and can result in loss of key species and ultimately a breakdown in habitat.<br>36 3 Planning for adaptation Example 8. Monitoring the attributes of the endemic Cloudey Island petrel. | Adapt-MitigImpacts | 33 - 34 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Human-induced fires are having an impact on important flora. Two of the lakes were stocked with non�native fish about seventy years ago, which may pose a threat to the native species, although the trends are not known.<br>37 Planning for adaptation 3 In conclusion, climate change vulnerability indicates the extent to which changes in climatic conditions are likely to cause a negative impact to the site's OUV. This is determined by: off-site stresses (e.g. future climate projections, surrounding landscape scale influences); on-site conditions (e.g. current state of conservation of rare species); and adaptive capacity (e.g. ability of management to take action to prevent negative outcomes). | Adapt-MitigImpacts | 34 - 35 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Outstanding Universal Value Sensitivity, Vulnerability, Resilience Features and attributes Capacity to adapt Context – World Heritage, climate change Climate change scenarios Potential options Assessing risk Implementation logistics Prioritizing action Monitoring and evaluation Tajik National Park (Mountains of the Pamirs) (Tajikistan). © Nomination file<br>40 3 Planning for adaptation Management systems The questions in Worksheet 4, adapted from the resource manual on Preparing World Heritage Nominations, 24 relate to management systems, and should be helpful in assessing vulnerability to climate change linked to site management. | Adapt-MitigImpacts | 37 - 38 |

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| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | General level of knowledge of the site Extensive Good Some knowledge Limited None General level of support for the site and its aims Negative Positive -5 -4 -3 -2 -1 0 +1 +2 +3 +4 +5 Particular areas of concern (if any) or opportunities for engagement Lack of trust? Past problems? Open antagonism? Breakdown in communication? Disagreements over rights? Etc.<br>42 3 Planning for adaptation Legal and policy context The ability to manage any World Heritage site (and to adapt to climate change impacts) will depend on the legal and policy support given by government, especially in relation to legal and policy issues that may potentially impact on a site's integrity, as well as the documentation that establishes its legal status. Additionally, many countries also have national strategies, policies and other legislation on climate change of which the site management should be aware. | Adapt-MitigImpacts | 39 - 40 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Build alliances with NGOs, businesses and landowners. Work with them to raise awareness of climate change. Work with adjoining landowners to enhance positive management and minimize negative impacts – encourage the control of pesticides, herbicides and fertilizers, especially where your site is 'downstream' of such land; encourage the naturalization of waterways and their shorelines. | Adapt-MitigImpacts | 43 - 43 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | http://www.indiawaterportal.org/; http://whc.unesco.org/en/ list/798 Expand the effective size of the site, by introducing a buffer zone if possible, in order to allow for movement and population growth. Encourage sustainable use/ alternative livelihoods with surrounding communities in the area, so as to minimize impacts on adjoining ecosystems. Where feasible, secure formal agreements for co-management of resources. | Adapt-MitigImpacts | 43 - 43 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Given that the site is also subject to coastal erosion, it is particularly important that clear, agreed national and local policies are harmonized and rigorously applied in order to protect its OUV in the context of the wider landscape. Various planning, coastal protection, agriculture, floodwater and access laws are used to regulate activities and to establish and enforce protective policies. | Adapt-MitigImpacts | 43 - 43 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | 3.7 Key issues in adaptation planning 1. Ensure that you take into account the dynamics of climate change when developing management plans. You will need to consider the possible effects of sea level rise, increased storm incidents, flood events, drought, glacial retreat, etc. These may include change in land cover, habitats and species; erosion and silting up; or changes in migration patterns. You may therefore need to plan for coastal realignment; diversion or blocking of watercourses; expansion or reshaping of your site; or relocation of any settlements away from threatened valleys or coasts. Your plan should demonstrate that you have thought about these things and considered a range of options. Do not produce plans as if there will be no changes to your site over the next decades. | Adapt-MitigImpacts | 45 - 45 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Rezoning the Great Barrier Reef In 2004 the Australian Government rezoned the Great Barrier Reef to increase protection to a range of species and resources. For example, the 'no take' areas were increased from 5 to 33 per cent, and 'no trawl' areas from 15 to 28 per cent of the park. One of the main reasons was the protection of the marine turtle, which had suffered from various impacts including fishing. Overall, the area that provided increased protection for the three marine turtle species from trawling rose from 30 to 70 per cent. | Adapt-MitigImpacts | 45 - 45 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | http://www.gbrmpa.gov.au/zoning-permits-and-plans/zoning<br>48 3 Planning for adaptation 2. Review the zoning system for your site. You may need to carry out interventions on parts of it, and allow for new patterns of movement and colonization by both humans and wildlife in and around the site. If applicable, review the management of visitors to reduce erosion, waste, disruption, litter and other impacts. | Adapt-MitigImpacts | 45 - 46 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | ca/~w3bio/bio464/lectures/lectures_assets/sustainability_ of_indigenous_hunting.pdf; T. Moore, 2010, http://www.culturalsurvival.org/ publications/cultural-survival-quarterly/peru/peru-people�parks-and-petroleum 3. Review the laws and regulations that may have an impact on the effectiveness of your management and ability to adapt. Consider how social and economic programmes are influencing decisions about land, water and energy use in the landscape within which your site is located.26 Finally, you need to bear in mind the following: Attempting to solve a problem for one feature of the site's OUV may create new problems for other features. It may therefore be useful to think in terms of so-called Limits of Acceptable Change (LAC).27 Some degree of change is always certain, and we should focus our management efforts where they will have the greatest impact on sustaining the OUV while mitigating the unwanted changes. Therefore, we need to calculate how much loss is acceptable within certain limits. Some changes (e.g. a 10 per cent reduction in the population of an umbrella species) may be acceptable 26 J. Ohl-Schacherer et al., 2007, The sustainability of subsistence hunting by Matsigenka native communities in Manu National Park, Peru, Conservation Biology, Vol. 21, No. 5, pp. 1174–85. | Adapt-MitigImpacts | 46 - 46 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Outstanding Universal Value Sensitivity, Vulnerability, Resilience Features and attributes Capacity to adapt Context – World Heritage, climate change Climate change scenarios Potential options Assessing risk Implementation logistics Prioritizing action Monitoring and evaluation<br>50 3 Planning for adaptation Climate predictions for a specific site should be seen as a way to develop a context, or as a way to understand how significant the issue might be. Although we do not have the capability to change future climatic conditions, being forewarned gives a context for scenario-building, which in turn allows possible responses to be planned. | Adapt-MitigImpacts | 47 - 48 |

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| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | While future climate conditions are very difficult to predict precisely, even rough predictions will help a manager to think about the ways in which the attributes of the OUV may be expected to respond to future climate conditions. This allows at least some form of risk analysis as the basis for designing an adaptation plan. Such a plan should provide a range of prioritized actions, both within and beyond the site itself. | Adapt-MitigImpacts | 48 - 48 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | ‘Coasts will be exposed to increasing risks such as coastal erosion due to climate change and sea-level rise’ ‘Increases in sea-surface temperature of about 1–3 °C (will) result in more frequent coral bleaching events and widespread mortality unless there is thermal adaptation or acclimatization by corals’ Increased exposure to higher turbulence from the sea Changes to marine biology Increased exposure of plateau scrub to salt spray Changes to reef pattern Increased exposure of beach to rising sea levels and turbulence Increase in tropical storm events Accelerated undermining of cliffs and caves Loss of prey species Loss of endemic invertebrates Coral bleaching Disruption to turtles nesting on the beach Loss of habitat and associated species ‘More and larger glacial lakes’ ‘Increasing rock avalanches ...’ ‘Increased run-off and earlier spring peak discharge in many glacier and snow-fed rivers’ ‘Changes affecting algae ... fish and zooplankton because of rising water temperatures and changes in: ice cover, oxygen levels, water circulation’ ‘Dry regions will get drier, and wet regions will get wetter’ ‘Spring events such as the unfolding of leaves, laying of eggs and migration are happening earlier’ ‘...pole-ward and upward (to higher altitude) shifts in ranges of plants and animal species’ Shorter periods of freezing Increased avalanche events Wetter conditions in some areas Changes to lake biology, as a result of increased eutrophication Drier, hotter conditions in high plateau areas Changes in habitat – loss or migration of some plant communities Increased silting downstream Catastrophic flooding as a result of glacial dam bursts New lakes formed from avalanche debris Increases in algal blooms Disruption to feeding/ breeding habits of key mammal species Loss of feeding grounds/ refuge sites for migrating birds Migration of prey species Increases in uncontrolled fire events 52 3 Planning for adaptation Example 10. Problem tree analysis. | Adapt-MitigImpacts | 49 - 50 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Hotter, drier conditions on plateau Loss of plant cover Loss of pollinating insects Increased number of uncontrolled ffres Changes in habitat structure Exposure and erosion of soils Incapacity of ffora to recover Loss of critical ffora Out-migration of herbivores Loss of key predators Increased water run-off Downstream impacts Rough predictions such as the above will help a manager to think about the ways that the attributes of the OUV may be expected to respond to future climate conditions (i.e. a risk analysis). The risk analysis forms the basis for designing an adaptation plan, which should relate to a spatial hierarchy of actions, both within and beyond the site itself (see Section 3.10 on adaptive actions). | Adapt-MitigImpacts | 50 - 50 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | http://www.metoffice.gov.uk/precis/ 53 Planning for adaptation 3 3.9 Understand likely OUV responses – analyse the risks A useful way of analysing the risk to a site’s OUV is to look at its key features and their attributes and assess the probability and significance posed by threats. For example: OUV feature Description of impact Reptile community of the site is among the most diverse in the world, with more than thirty-five species, 90 per cent of which are endemic Invasive predator damages populations Increased fire frequency changes vegetation, reducing habitat Reduced precipitation results in loss of wetland habitat Increased storm frequency and intensity results in eroded and sediment-laden habitats Phenology of spring grasses alters food for major prey during breeding season OUV feature Description of impact Probability Significance Reptile community Invasive predation on reptiles Fire frequency degrades habitat Precipitation frequency causes loss of wetlands Storm frequency and intensity damages habitats Phenology of spring grasses alters food for major prey during breeding season Improbable (low) Insignificant (low) Possible (medium) Significant (medium) Probable (high) Highly significant (high) Outstanding Universal Value Sensitivity, Vulnerability, Resilience Features and attributes Capacity to adapt Context – World Heritage, climate change Climate change Potential scenarios options Assessing risk Implementation logistics Prioritizing action Monitoring and evaluation Obviously the less resilient a site is, and therefore the more vulnerable it is to climate change, the higher the risk that it will suffer negative impacts from changes in climate. For the manager, the task is first to identify the sources of those risks, then to determine: – How likely are they to occur? | Adapt-MitigImpacts | 50 - 51 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Some events might be highly likely, but not significant to the OUV of a site. Others might be highly unlikely but disastrous if they do occur. A risk analysis is designed to help to identify outcomes that would be both relatively likely and relatively significant, and would therefore demand priority management attention. 54 3 Planning for adaptation In this example the site manager will focus efforts on improving capacity to manage fire in specific areas where damage to reptile habitat is most likely, while establishing a rigorous monitoring programme for the presence of invasive species. | Adapt-MitigImpacts | 51 - 52 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | An analysis of this sort allows the manager to identify key actions to sustain the OUV. Risk assessment is not a perfect science – it is informed guesswork based on the intuition, insights and expertise of the management team and colleagues, but it does provide a basis for focusing on issues that might otherwise be missed. This kind of assessment is therefore always most effective when carried out by a team that understands socio-economic as well as ecological dimensions. | Adapt-MitigImpacts | 52 - 52 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Outstanding Universal Value Sensitivity, Vulnerability, Resilience Features and attributes Capacity to adapt Context – World Heritage, climate change Climate change scenarios Potential options Assessing risk Implementation logistics Prioritizing action Monitoring and evaluation Example 11. Prioritizing management actions at Cloudey Island. | Adapt-MitigImpacts | 53 - 53 |

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| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | The Cloudey Island management team has assessed the risks to two of the features that contribute to their OUV, and then considered their possible responses against a set of criteria. They have also considered whether there are likely to be any conflicts between their responses and other features and attributes that contribute to the OUV. | Adapt-MitigImpacts | 53 - 53 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | The risk from climate refugees is not seen as an immediate threat, but it is a possibility, and work needs to be done to minimize this risk. 57 Planning for adaptation 3 Worksheet 9: Prioritizing action against criteria Possible response actions Criteria Priority actions 3.11 Implement your plan This section deals with some of the practicalities of implementing your responses. Much of this should be familiar in the context of management and action planning. | Adapt-MitigImpacts | 54 - 55 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Outstanding Universal Value Sensitivity, Vulnerability, Resilience Features and attributes Capacity to adapt Context – World Heritage, climate change Climate change Potential scenarios options Assessing risk Implementation logistics Prioritizing action Monitoring and evaluation 58 3 Planning for adaptation Example 12. Action plan and related tasks at Cloudey Island. | Adapt-MitigImpacts | 55 - 56 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Having listed the tasks linked to each option, the management team has now agreed on a logistical plan for implementing the tasks. It recognizes the need to start a training programme and to set up the system early on, and has timed its activities to coincide with appropriate seasonal factors such as breeding and rearing, different weather events, and optimal trapping times. It appreciates the need to minimize human presence on the island, and has timed monitoring activities to coincide with each other where possible, as this will also optimize logistics and minimize impact. | Adapt-MitigImpacts | 56 - 56 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Monitoring small isolated ecosystems such as pools, wetlands, wooded areas and scrubland will assist in assessing ecosystem-scale impacts. These small systems contribute disproportionately to regional landscape diversity, have easily assessed communities and physical structure, and serve as stepping stones in the landscape, facilitating plant and animal movements.30 At the community and ecosystem scale, climate monitoring has also demonstrated rapid recent changes across a landscape. For example, alpine streams in Switzerland have warmed, shown reduced nitrogen concentrations and reduced taxa richness and density of zooplankton in only a few decades.31 30 L. de Meester et al., 2005, Ponds and pools and model systems in conservation biology, ecology and end evolutionary biology Aquatic Conservation: Marine and Freshwater Ecosystems, Vol. 15, pp. 715–25. | Adapt-MitigImpacts | 58 - 58 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | 36 http://www.bto.org/science/international/out-africa 37 http://www.birdlife.org/africa Outstanding Universal Value Sensitivity, Vulnerability, Resilience Features and attributes Capacity to adapt Context – World Heritage, climate change Climate change scenarios Potential options Assessing risk Implementation logistics Prioritizing action Monitoring and evaluation<br>61 Planning for adaptation 3 Where appropriate, managers of African World Heritage sites might focus on such migrations as indicators of climate change, partly because of the contribution such observations would make to global research but also because these data are not well known, so careful data collection might be especially informative. Likewise, larger migratory animals provide essential information on changes in seasonal vegetation patterns. Scientists have successfully associated animal migrations and insect emergences with fine-scale climatic patterns.38 Amphibian communities in particular have shown the most dramatic climate change responses to date.39 In one study, autumn breeding amphibian populations are breeding later and winter breeding species are breeding earlier, with changes ranging from 5.9 to 37.2 days per decade.40 38 D. Senepathi et al., 2011, Climate change and the risks associated with delayed breeding in a tropical wild bird population, Proceedings of the Royal Society Part B – Biological Sciences, Vol. 278, pp. 3184–90. | Adapt-MitigImpacts | 58 - 59 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | As described in Tool 11 of Enhancing our Heritage Toolkit, monitoring and assessment can help the site team to clarify its perception of climate change risks, its adaptive strategy, and the effectiveness of the adaptation actions it has decided to implement. As part of designing an effective assessment, the team will need to develop a range of indicators to measure the key outcomes from the adaptation plan; these should be directly related to the attributes of the site OUV. | Adapt-MitigImpacts | 59 - 59 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Source: National Academy of Sciences (2002), http://www.pnas.org/content/99/21/13379<br>3 Planning for adaptation 62 Monitoring is always limited by available resources, so the results and interpretations of a monitoring programme should be framed appropriately. For example, the experimental design (i.e. kinds and numbers of samples collected at various places and times) will dictate how well the site team understands the natural variance and the effects of an intervention such as an adaptation practice. Monitoring results might be phrased as statistically significant differences or as differences observed and recorded anecdotally. It will usually be valuable to consult a statistician, perhaps through a local university or ministry office, to assist with design and interpretation of monitoring results. | Adapt-MitigImpacts | 59 - 60 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | However, at regular timepoints during a programme, the management team should periodically pause and reflect on how effectively the site is being managed as well as how clearly the team understands the effects of its management. | Adapt-MitigImpacts | 62 - 62 |

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| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | As well as evaluating the effects of any climate change adaptation strategy, it is important to recognize the need to evaluate the monitoring programme itself. Managers need to ensure that monitoring has been systematic, objectively verifiable, appropriately timescaled, adequately resourced, efficiently carried out and targeted at measurable and relevant indicators. | Adapt-MitigImpacts | 63 - 63 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Worksheet 11 summarizes a range of climatic factors and approaches to recording them. It is generic, not comprehensive, and requires adaptation to local circumstances, but may be a useful starting point in recording climate patterns and effects over the following decades. | Adapt-MitigImpacts | 63 - 63 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Application Deadline Varied Amount Varied URL Link http://www.thegef.org/gef/ The Adaptation Fund Eligibility Country Eligibility Developing country Parties to the Kyoto Protocol that are particularly vulnerable to the adverse effects of climate change including low-lying and other small island countries, countries with low-lying coastal, arid and semi-arid areas or areas liable to floods, drought and desertification, and developing countries with fragile mountainous ecosystems. | Adapt-MitigImpacts | 74 - 74 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Water quantity and quality at Ichkeul is crucial to ensure a wetland ecosystem suitable for the migratory birds. The site lies at the bottom of a watershed and is separated from the sea via a small waterway leading to a salt lagoon. For this reason, the wetland's salinity is affected by the volume of water flowing into it. In the summer, salinity increases as water inflow decreases. In the winter, the reverse holds true – resulting in a delicate balance which provides suitable habitat quality for migratory birds. However, during prolonged Ichkeul National Park (Tunisia). © UNESCO/Marc Patry<br>84 6 Appendices droughts, and as sea levels rise, more sea water invades the wetland, increasing salinity to the point of having a detrimental impact on habitat quality. Compounding the challenges faced by the management agency, upstream capture and diversion of freshwater is increasingly an issue. The water is used to meet the needs of Tunisia's capital city, Tunis. | Adapt-MitigImpacts | 80 - 81 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | In this respect, a climate change mitigation project in the lands abutting the western boundary of this site may help to avoid a future scenario whereby local communities are compelled to turn to the World Heritage site for subsistence, thus undermining its Outstanding Universal Value. The Kariba REDD+ (United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries) project, certified under recognized international carbon verification standards, is selling carbon credits and funds are being applied to help communities improve agricultural practices, stabilize land use, and restore degraded forests. In so doing, the project will be improving the resilience of the World Heritage site, reducing the risk of incursions from surrounding communities in an age of climate change – when droughts are expected to be more common and severe. The project will also strengthen the connectivity of the site to the broader landscape, further supporting site resilience. | Adapt-MitigImpacts | 82 - 82 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | The World Heritage Centre has developed this practical guide to assist those responsible for the management of natural World Heritage sites to better understand how climate change may affect those features of the site that contribute to its Outstanding Universal Value and offer ideas for identifying options for adapting to climate change with tailored management responses. The purpose is to ensure the World Heritage site's resilience in the face of climate change, and therefore to sustain its Outstanding Universal Value. | Adapt-Mitig | 5 - 5 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | This guide helps site managers to analyse climate change threats and how they are likely to influence management objectives. It should enable site managers to factor climate change into management and action planning and feed into an existing management plan where one is already in place (e.g. | Adapt-Mitig | 9 - 9 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Other uses of such a plan might include making bids for funds and clarifying how those funds might be used, or taking opportunities to tap into funds from current programmes in national land planning, management planning or climate change. | Adapt-Mitig | 9 - 9 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Other guides, especially UNESCO World Heritage Centre's Enhancing our Heritage Toolkit, 4 can be useful where climate change concerns need to be integrated into wider management considerations. | Adapt-Mitig | 9 - 9 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | The purpose of management in this context is to ensure the World Heritage site's resilience in the face of climate change, and therefore to sustain its Outstanding Universal Value (OUV). | Adapt-Mitig | 9 - 9 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Most of the elements described in this guide are identical to management planning processes, and they should be used alongside the production of a management plan where possible, to avoid unnecessary costs and duplication. Where an up-to-date management plan is in place, much of the data and thinking may already exist, and need not be repeated. | Adapt-Mitig | 9 - 9 |

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| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Think in terms of a ‘toolbox’ of adaptation practices rather than single solutions. These should apply across a range of spatial and temporal scales. | Adapt-Mitig | 10 - 10 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | On the other hand, a convincing, evidence-based plan for adaptation will provide a strong case for funding. | Adapt-Mitig | 10 - 10 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | 5 For a guide to performing a problem tree analysis, see FAO, 2002, Community-Based Forest Resource Conflict Management, Training Package, Section 9.2, Exercise 8, Rome, Food and Agriculture Organization of the United Nations. | Adapt-Mitig | 10 - 10 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | http://whc.unesco.org/en/guidelines/ Table 1: Explanation of key terms Term Meaning Example Outstanding Universal Value (OUV) A natural site is considered to have OUV when it: (i) meets one or more of the four natural heritage criteria (see p. 24), (ii) satisfies conditions of integrity and/or authenticity, and (iii) has an adequate protection and management system to ensure its safeguarding. | Adapt-Mitig | 12 - 12 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | A site that contains a globally rare, endemic species, and thus provides it with the refuge, feeding and breeding conditions that sustain its population, could be said to have OUV provided its integrity can be maintained and it is effectively protected by legislation and effective management. | Adapt-Mitig | 12 - 12 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Wetlands may be a feature of a larger management area. But within a wetland there may be features such as pools, wet scrub, bogs, reed marsh and so on. | Adapt-Mitig | 12 - 12 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | At the end of a programme, or periodically, an organization might assess what activities have been carried out, what results have been achieved (outputs) and at what cost (inputs) in order to assess their effectiveness. Evaluation is also a review tool for management. | Adapt-Mitig | 13 - 13 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | We recognize that cooperation with communities neighbouring World Heritage sites is crucial in the implementation of adaptation strategies. In this respect, those responsible for identifying and implementing these strategies should also consider their community and gender-related implications. Every effort should be made to ensure participation of local and indigenous communities in climate change decision-making so that adaptation strategies contribute to the well-being of the communities, including marginalized groups, and avoid strengthening existing inequalities. Knowledge possessed by indigenous peoples also contributes to climate change assessment and adaptation by offering observations and interpretations at a much finer spatial scale with considerable temporal depth and by highlighting elements that may not be considered by climate scientists. | Adapt-Mitig | 13 - 13 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | There is a growing body of work on climate change and gender. A short list of useful resources is provided below: Gender Climate Change platform for information, knowledge, and networking on gender and climate change. http://www.gendercc.net/ Global Gender and Climate Alliance – Incorporating a gender perspective in all climate change policies and initiatives. http://www.gender-climate.org/ González, A. M. and Martin, A. S. 2007. Gender in the Conservation of Protected Areas. Parks in Peril, Innovations in Conservation Series. Arlington, Va., The Nature Conservancy. http://www.cbd.int/doc/pa/ tools/Gender%20in%20the%20conservation%20 of%20protected%20areas.pdf IUCN, UNDP, GWA, ENERGIA, UNESCO, FAO and WEDO as part of the Global Gender and Climate Alliance (GGCA). 2009. Training Manual on Gender and Climate Change. San José, Absoluto. https://portals.iucn.org/ library/efiles/documents/2009-012.pdf UNDP. 2013. Africa Adaptation Programme Experiences: Gender and Climate Change. New York, United Nations Development Programme. | Adapt-Mitig | 14 - 14 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | To be inscribed on the World Heritage List, a site must have Outstanding Universal Value (OUV). OUV implies ‘cultural and/or natural significance which is so exceptional as to transcend national boundaries and to be of common importance for present and future generations of all humanity. As such, the permanent protection of this heritage is of the highest importance to the international community as a whole.’ (UNESCO World Heritage Centre, 2013, para. 49). | Adapt-Mitig | 16 - 16 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | States Parties to the World Heritage Convention have the responsibility to ensure the identification, nomination, protection, conservation, presentation, and transmission to future generations of the cultural and natural heritage found within their territory. All properties inscribed on the World Heritage List must have adequate long-term legislative, regulatory, institutional and/or traditional protection and management to ensure their safeguarding. This guide can help countries to carry out some of these obligations. | Adapt-Mitig | 16 - 16 |

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| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | 6) There are no obviously recognizable alternative solutions that are better. There may be many possible solutions, some already tried elsewhere, some not yet identified. By its nature, adaptation is about trial and error, using emerging knowledge, understanding, creativity and judgement based on experience. | Adapt-Mitig | 18 - 18 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Think beyond the spatial boundary Address the site in its broader landscape (Figure 3). The most successful climate change adaptation strategies view the site as an element of a larger landscape and then address the OUV on-site in the context of off-site practices that influence the OUV. | Adapt-Mitig | 19 - 19 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Climate change adaptation requires analysis of the current situation and the projected changes, measuring the results of actions taken, revising them and trying again. Adaptive management is based on this cycle of analysis, application, evaluation and revision (Figure 4). | Adapt-Mitig | 19 - 19 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Hydro dam Settlements Settlements<br>22 2 Understanding the context Approach the problem at different levels using different methods Adaptation responses take place at different levels. Small, site-specific, lower-level actions can be taken on most sites. | Adapt-Mitig | 19 - 20 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Cloudey Island meets criterion vii – it contains superlative natural phenomena and areas of exceptional natural beauty and aesthetic importance. The island also meets criterion x, as it contains the most outstanding and significant natural habitats for in situ conservation of biological diversity, including threatened species of Outstanding Universal Value. | Adapt-Mitig | 23 - 23 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Does the site have a buffer zone? If so, is it under any threat?<br>28 3 Planning for adaptation All World Heritage sites should have a Statement of Outstanding Universal Value (SOUV). Because it is impossible to list and describe every possible element of sites, these statements try to summarize those aspects that provide the foundation for World Heritage status (see Example 4). | Adapt-Mitig | 25 - 26 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Many resources are available for support in documenting natural conditions. Enhancing our Heritage Toolkit, 14 especially Tool 1, ‘Identifying site values and management objectives’, is particularly useful in understanding this step. | Adapt-Mitig | 26 - 26 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | This can be a difficult concept to grasp, but it is central to effective site management. What counts as a feature depends on the spatial scale of a site. Some large areas may have few features, while other areas may have many. The best way to consider features is to simply list those things that are considered most important. The OUV statement will help you to identify them. | Adapt-Mitig | 27 - 27 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | 1) Fossil raised reef 2) Karst cliffs, caves and pinnacles 3) Reef fish species 4) Natural scrub forest 5) Ten species of endemic vascular plants (1–10 listed) 6) Invertebrate species 7) Reptiles/turtles 8) Seabirds 9) Four species of landbird including the Cloudey Island petrel (1–4 listed) These are fairly general, and in the case of Cloudey Island only one specific species was named as a feature in the site's Statement of OUV – the Cloudey Island petrel. Good management dictates that as far as possible all species that constitute a key feature are listed, but this depends on the capacity of the management staff. | Adapt-Mitig | 28 - 28 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Site feature 4 Attributes Natural scrub forest Extent and distribution Canopy cover – percentage of closed/open canopy Species composition – relationship between different indigenous species/indigenous�introduced species Regeneration – rate of regeneration/growth/death for each species Dead wood – abundance of standing and fallen dead wood Understorey and ground flora – abundance and composition of species at different levels Precipitation, temperature, frequency of storm events, wind conditions In order to monitor these features, each of their attributes must be understood (see Example 6). Attributes are what any feature needs to make it function, and which can be observed. These include feeding, sheltering, breeding, predation, migration patterns, and other factors such as hunting, pollution, etc. They might include extent, variety, age, extraction and regrowth rates for forests, or abstraction and recharging, biological and chemical composition in watercourses. All these attributes can be directly measured and observed, and will provide the evidence for managing change and responding to it. 31 Planning for adaptation 3 Site feature 5 Attributes (for each endemic vascular plant) Plant 1, 2, 3, etc. | Adapt-Mitig | 28 - 29 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | As well as providing the basis for monitoring pressures and trends, this systematic approach allows the manager to set clear objectives that can be monitored. The aim of managing any natural World Heritage site is to maintain and enhance its OUV, but this is meaningless unless clear objectives and management targets can be set (see Example 7 and Worksheet 3). | Adapt-Mitig | 29 - 29 |

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| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | In the case of extensive, remote natural sites exposed to few anthropogenic threats, the objectives may be relatively straightforward – perhaps no more than monitoring the attributes and reporting. Smaller more sensitive sites may require more intervention to maintain their integrity, and the objectives may need to reflect this. Some sites may include specific cultural and economic, as well as natural objectives, under different headings – you will need to ensure these do not conflict.<br>32 3 Planning for adaptation Example 7. The case of the Snowey Mountains System demonstrates the link between aims, features, attributes and management objectives. | Adapt-Mitig | 29 - 30 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | For these reasons it is in everyone's interest to protect and enhance such sites. In this guide, sensitivity and vulnerability are seen as separate but linked concepts. A site may be sensitive for many reasons. It may be too small to resist a number of pressures; key species populations might be at critical levels with little room to manoeuvre, or its Value of protected areas for climate change mitigation and adaptation Protected areas play a major role in reducing climate�changing carbon dioxide emissions in the atmosphere. | Adapt-Mitig | 31 - 31 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Giant leaf frog, Amazon National Park – many amphibians have very specific climatic requirements and their populations change rapidly as climatic conditions change. Therefore, amphibians are often sensitive indicators of climate change. © Dawn Tanner and Jim Perry<br>35 Planning for adaptation 3 Table 2: Possible threats posed by climate change in different habitats/landscape types Habitat/ landscape type Possible threats High mountain range Glacial melt leads to inundation of valley habitats and communities. | Adapt-Mitig | 32 - 33 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Is there a protocol for government support should the need arise in the case of critical events?<br>41 Planning for adaptation 3 Stakeholders Adaptive capacity includes your relationship to the communities around you, without whose support effective responses to the threat of climate change would be impossible. You also need to understand your other partners and stakeholders – what motivates them, how they relate to the site, and their negotiating positions (see Worksheet 5). Different people and groups need different kinds of approaches – some will be less confident in large meetings, or may be unable to express their concerns. | Adapt-Mitig | 38 - 39 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Some may be hostile to World Heritage site management for complex reasons that are important to recognize. For a complementary worksheet on engagement of stakeholders, please see Enhancing Our Heritage Toolkit. | Adapt-Mitig | 39 - 39 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | It is therefore important to review how the government influences site management, by analysing its commitment through national laws, through the policies it promotes, and through the international laws, treaties and conventions it actively supports (see Worksheet 6). | Adapt-Mitig | 40 - 40 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Title Policies Relevance to OUV Title Statement/reference<br>43 Planning for adaptation 3 Site design Site boundaries are defined under the terms of the World Heritage inscription. However, they may not reflect the ecological patterns and systems that support ecosystem functions such as prevailing rainfall patterns, migration, hydrological systems, variations in habitat types, and so on. | Adapt-Mitig | 40 - 41 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Many natural World Heritage sites are surrounded by a buffer zone that may be more or less under the control of the site management agency, and/or for which there may be specific land-use policies in place designed to support the integrity of the site. The existence, the size and design, and the actual management implications of buffer zones vary widely among sites. Ecological connectivity within the buffer zone and beyond is a crucial factor in the site's resilience – particularly for smaller sites (e.g. less than 10,000 ha). | Adapt-Mitig | 41 - 41 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | On their own, such interventions may not prove successful, and a raft of other initiatives may need to be taken. Some of these may entail paying or compensating surrounding communities to do or to avoid doing something that might influence the resilience of the site; optimizing people's interests in supporting the protection of wildlife and ecosystems by raising awareness of their values and by giving people a stake in their protection; persuading politicians or the private sector of the importance and expediency of protecting the OUV of World Heritage sites; and generating the support of the global community in the protection of such sites. | Adapt-Mitig | 42 - 42 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | In general, adaptation practices should conserve the geophysical stage, protect refugia, and promote connectivity within the greater landscape. Some interventions require hard engineering, such as artificial reefs, breakwaters, roads, canals, removing invasive species, re-vegetation, managing dunes, restoring wetlands, or burning. Others focus on changing human behaviour, such as education, zoning, taxation, legislation, or social programmes.25 Significant engagement with stakeholders in the surrounding land/ 25 See for example, A. Travers et al., 2012, Ecosystem-based Adaptation Guidance – Moving from Principles to Practice, Nairobi, United Nations Environment Programme. | Adapt-Mitig | 42 - 42 |

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| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Work with national planning and development agencies to include conservation and enhancement of OUV in all policies and plans, including sustainable development strategies, spatial plans, requests for funding, action plans, district and regional development plans, poverty reduction strategies, etc. | Adapt-Mitig | 43 - 43 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Integrated protection of World Heritage The Canadian Government has integrated protection of World Heritage properties into comprehensive planning programmes. Where World Heritage sites are administered by Parks Canada, site authorities participate in land- and resource-use planning processes beyond the site's boundaries to ensure that the World Heritage values are recognized in spatial strategies. Where sites are owned by the provinces, municipal planning activities must take into account the values of the sites. Environmental assessment legislation is also widely used to ensure that alternatives and mitigation of threats are applied when considering proposals. | Adapt-Mitig | 43 - 43 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | http://www.jurassiccoast.com/downloads/spatial_planning_ research_project_-_luc.pdf South Africa has a national climate change response strategy (2004) containing twenty-two key actions including 'Develop protection plans for plant, animal and marine biodiversity'. | Adapt-Mitig | 43 - 43 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | http://unfccc.int/files/meetings/seminar/application/pdf/ sem_sup3_south_africa.pdf 46 3 Planning for adaptation Form alliances with managers of other natural World Heritage sites and protected areas within the area of influence of your site if possible, to ensure effective communication about migratory species such as birds, butterflies or large mammals. | Adapt-Mitig | 43 - 44 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Managing with fire The plant and animal communities of many arid and semi-arid landscapes have evolved to depend on fire. In these landscapes, fire removes or controls invasive plants, releases nutrients and opens certain kinds of seeds. Fires have been a natural part of ecosystem function for millions of years and part of human-induced management for thousands. The fire-adapted landscapes of South Africa, including Cape Floral Region (http://whc.unesco.org/en/list/1007) and Vredefort Dome (http://whc.unesco.org/en/ list/1162) World Heritage sites, are examples of such landscapes. Intentional fire management through controlled burns can serve to protect the OUV of these fire-dependent areas. | Adapt-Mitig | 44 - 44 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Focus on preserving and strengthening existing biological corridors. 47 Planning for adaptation 3 Hard engineering: Case of Mount Kenya Mount Kenya National Park hosts significant numbers of elephants, but much of the surrounding landscape is farmed. Kenya Wildlife Service, with the support of many partners including Kisima Farm, the Bill Woodley Mount Kenya Trust, the Ngare Ndare Forest Trust and the Lewa Wildlife Conservancy is increasing options for elephant movement in response to changing conditions. The most ambitious project has been a wildlife underpass, allowing animals to cross highways in safety. The underpass opened in January 2011 and has already proved to be beneficial to wildlife and in increasing connectivity to improve ecosystem resilience. | Adapt-Mitig | 44 - 45 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Provide funding and support to retain or convert these sites from inappropriate land uses, using management agreements. Establish community reserves. Consider engaging in payment for ecosystem services (PESs) programmes, including REDD+ initiatives (see page 76), as a means of securing financing and local support for activities that will require concerted, landscape level participation. | Adapt-Mitig | 45 - 45 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Greater Yellowstone Co-ordinating Committee Three federal agencies are represented on Greater Yellowstone Co-ordinating Committee (GYCC, http://fedgycc.org/), responsible for nearly 53,000 km2 of protected and managed land, including Yellowstone National Park. The GYCC has developed a range of climate change mitigation strategies and practices to be implemented by its state and federal members, and a wide range of adaptation strategies, mainly focused on large wildlife and ecosystem function. Cooperative agreements have led to co-management of very large areas of land, ensuring the sustainability of large, migratory and charismatic species such as American bison and elk. In some states, legal instruments exist which allow landowners to voluntarily cede the right to use their land in certain ways, in exchange for property tax reductions or other forms of recognition. | Adapt-Mitig | 45 - 45 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Indigenous peoples: Case of Manú National Park26 Manú National Park in Peru, like many large forested World Heritage sites, is home to resident indigenous communities, who carry out a wide range of subsistence activities within the park including hunting. With new technology come new practices, in this case changing a bow and arrow to a shotgun has taken its toll on game populations. This is mitigated in Manú by a policy that bans firearms inside the site, alongside targeted development activities to encourage people to support conservation. There is, however, evidence that outside interests may pose a threat to the indigenous communities and continuity of their traditional lifestyles. | Adapt-Mitig | 46 - 46 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Thinking beyond borders: Case of Monarch Butterfly Biosphere Reserve The Monarch Butterfly Biosphere Reserve in Mexico, where protecting the OUV relates to the migratory phenomenon, requires management interventions not only at the site, but throughout the butterfly's migratory range, which includes Canada and the United States. Although site managers cannot engage with governmental bodies outside their country, they can ensure that appropriate national government agencies are informed of issues that might require international coordination. | Adapt-Mitig | 46 - 46 |

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| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | GCMs use knowledge of atmospheric physics and historical climates to model temperature and precipitation. Each GCM operates with different assumptions and internal relationships. Because no single GCM is universally correct, most climatologists and other scientists consider it good practice to use several models and express predicted future conditions as the mean of those predictions. However, it is also essential to incorporate variance among the models as a measure of uncertainty.28 GCMs are useful in understanding broad climate patterns and in describing the potential, coarse-scale future conditions to which a site might be exposed. However, they are not useful for predicting the specific conditions that might be experienced by plant, animal or human communities in and around a World Heritage site. Also, our ability to precisely predict future climates is currently limited to a few decades and is better for temperature than precipitation. The lack of precision for precipitation and long-term predictions is a significant limitation in planning management strategies for a site. | Adapt-Mitig | 47 - 47 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Set baselines against the outcomes and monitor against these baselines Develop a set of attributes and their indicators to reffect the major site features Identify the features that need to form the basis of the monitoring plan Identify OUV responses to a breach of the thresholds Compare data needed with existing monitoring processes/data and identify gaps Develop a data management system Develop detailed monitoring standards that deffne monitoring purposes, methodologies, etc. to ensure replicability and credibility Agree thresholds including climate-related ones that would trigger concerns Figure 8: Setting up a monitoring plan, adapted from Enhancing our Heritage Toolkit (Hockings et al., 2008). | Adapt-Mitig | 60 - 60 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Prior to carrying out the monitoring programme, the management team has reviewed the amount and location of appropriate habitat, and identified a representative number of monitoring sites. It has decided to carry out its work in mid-March, to allow for a build-up of scats and scrapes at the end of the mating season, while preserving tracks in the snow where it has built up between cliff bottoms and slopes, and along ravine edges, favoured snow leopard sites. This means that humans and livestock have yet to be active in the area. On the other hand, some areas will be inaccessible because glacial melt-water has swollen the rivers. | Adapt-Mitig | 61 - 61 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | This section has discussed monitoring in terms of the options and actions in relation to climate change adaptation, but of course monitoring is a continuous aspect of protected area management generally and World Heritage site management in particular. Bearing in mind the dynamics of climate change, and the need for constant adjustments, there is no end point. | Adapt-Mitig | 62 - 62 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | In order to sustain a site's OUV despite climate change, a manager needs to evaluate both the processes through which management is achieved as well as the specific attributes that contribute to the OUV. Lessons learned will help the team to refine the adaptive strategy, increasing the probability that the OUV will be sustained. | Adapt-Mitig | 62 - 62 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | You should not underestimate the demands of time and resources in developing an adaptation strategy, and it might be appropriate to carry out this work while revising or producing your management plan, or in conjunction with the development of wider land management strategies and plans. | Adapt-Mitig | 66 - 66 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Expertise in climate change adaptation is growing among the protected area management community, and it is important to keep up to date by reviewing UNESCO World Heritage Centre and IUCN websites, as well as those of international and national NGOs. An increasing number of case studies and examples of strategies is available on the internet, including those referred to here, and they are a valuable source of information. | Adapt-Mitig | 66 - 66 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | In conclusion, the following points are worth reiterating: Climate change is a highly complex process, and we cannot predict in detail what future climate conditions might be. However, we can develop some consensus on likely scenarios based on observation, knowledge and expertise, and professional intuition. What is clear is that change is on the way.<br>69 Conclusion 4 The focus of natural World Heritage management is the protection of its Outstanding Universal Value (OUV). | Adapt-Mitig | 66 - 67 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Implementing and Executing Entities Eligible Parties who seek financial resources from the Adaptation Fund shall submit proposals directly through their nominated National Implementing Entity (NIE). They may, if they so wish, use the services of Multilateral Implementing Entities (MIE). The implementing entities shall obtain an endorsement from the government. | Adapt-Mitig | 74 - 74 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | The European Commission has approved funding for 183 new projects under the fourth call for the LIFE+ programme (2007-2013). The projects are from across the EU and cover actions in the fields of nature conservation, environmental policy, and information and communication. Overall, they represent a total investment of €530 million, of which the EU will provide €244million. | Adapt-Mitig | 77 - 77 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | In response to these challenges, the Government of Tunisia has, over several years, installed water-flow control structures at the outflow point of the wetland. The structures help to keep out excess salt water during droughts, while letting water out during particularly wet periods. Upstream, management agreements between various user groups have been developed, ensuring a minimum water flow to the park during critical times. Together, these measures have helped Ichkeul National Park to improve its resilience to drought and sea level rise. | Adapt-Mitig | 81 - 81 |

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| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | The government embarked on an ambitious infrastructure programme that included an 18 km pipeline, local water retention and management infrastructure and a river diversion scheme. | Adapt-Mitig | 81 - 81 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | This site is surrounded by subsistence-level communities, who work the land and gather forest products to make their living. Conditions can be difficult, and food security Water management infrastructure, Keoladeo National Park (India). | Adapt-Mitig | 81 - 81 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | The intimate link between the World Heritage site and the project area was used to raise the interest of potential buyers of carbon credits on the voluntary market. There are more sellers of carbon credits than there are buyers. Under these circumstances, using the connection to nearby World Heritage sites, and demonstrating how a REDD+ project will support World Heritage site adaptation to climate change, may help to attract potential carbon credit buyers. | Adapt-Mitig | 82 - 82 |
| UNESCO | Climate Change Adaptation for Natural World Heritage Sites - UNESCO 2014 | Designing for resilience: Area de Conservación Guanacaste (Costa Rica) and Manú National Park (Peru) Perhaps the best approach to ensuring climate change adaptation is to create protected areas that, by their very design, offer greater resilience to any stresses. Some World Heritage sites enjoy a 'built-in' resilience thanks to their overall design from the outset. They are large, and cover wide climatic gradients, connecting lowlands to highlands, dry areas to wet areas. As temperature and moisture gradients shift over the years, the values of these sites should be better able to adapt to such shifts. One additional supporting strategy is having a site embedded into a larger protected landscape. 86 6 Appendices The Area de Conservación Guanacaste in Costa Rica (inscribed 1999, extension 2004) extends from sea level on the Pacific Ocean, over coastal hills and into interior valleys, before rising to the cool mountain tops inland at 1,500 m altitude. | Adapt-Mitig | 82 - 83 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The World Heritage Committee has recognized this emerging threat and responded at its 29th session by launching an initiative to assess the impacts of climate change impacts on World Heritage and define appropriate management responses. Accordingly, a meeting of experts was held in March 2006 in order to prepare a Report and a Strategy to assist States Parties in addressing this threat, and these documents were endorsed by the Committee at its 30th session in July 2006. | Adapt-MitigImpacts | 4 - 4 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Protecting and managing World Heritage sites in a sustainable and effective manner is a shared responsibility under the Convention. Therefore, there is a need to publicize all available information on the threats posed by climate change and the potential measures for dealing with them. This pub�lication in the World Heritage Papers Series, comprising the report on 'Predicting and managing the effects of climate change on World Heritage' and a 'Strategy to assist States Parties to implement appropriate management responses' is part of that overall effort. | Adapt-MitigImpacts | 4 - 4 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | This Convention provides for countries to cooperate in preparing for adaptation to the impacts of climate change; develop and elaborate appropriate and integrated plans for coastal zone manage�ment, water resources and agriculture, and for the protection and rehabilitation of areas, particu�larly in Africa, affected by drought and desertification, as well as floods. | Adapt-MitigImpacts | 6 - 6 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Parties to the UNFCCC are: developing and submitting national reports containing inventories of greenhouse gas emissions by source and removals by sinks using agreed guidelines, adopting national programmes for mitigating climate change, developing strategies for adapting to its impacts, promoting technology transfer and the sustainable management of resources, enhancing greenhouse gas sinks and reservoirs (such as forests). In addition, the countries are taking climate change into account in their relevant social, economic, and environmental policies and cooperating in scientific, technical, and educational matters, as well as public awareness. | Adapt-MitigImpacts | 6 - 6 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | In order to respond to the needs for assessing the impacts, vulnerability and adaptation, the UNFCCC secretariat has created a compendium on methods and tools to evaluate adaptation options and web pages to facilitate access to information on methods to evaluate adaptation options. It has conducted expert meetings and workshops with the participation of intergovernmental organizations, United Nations organizations and the community of users to identify opportunities for cooperation. | Adapt-MitigImpacts | 7 - 7 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | In 2006, the secretariat produced a technical paper on the application of environmentally sound tech�nologies for adaptation to climate change. This paper contains an overview of: the current knowl�edge and understanding of adaptation to climate change, a framework for assessing technologies for adaptation to climate change, the process of technology development and transfer as relevant to adaptation to climate change, examples of important technologies for adaptation in five sectors (coastal zones, water resources, agriculture, public health, and infrastructure), together with three case studies for each sector, and a synthesis of findings that have implications for climate policy. The paper argues that many technologies exist to adapt to natural weather-related hazards and that these technologies can also play an important part in reducing vulnerability to climate change. Hard and soft technologies are available to develop information and raise awareness, to plan and design adaptation strategies, to implement adaptation strategies, and to monitor and evaluate their per�formance. The paper provides examples of technologies that can be employed to accomplish them. | Adapt-MitigImpacts | 7 - 7 |

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| UNESCO | Climate Change and World Heritage - UNESCO 2007 | PM_ClimateChange_22 UK 2/05/07 11:55 Page 6<br>7 Realizing the need to obtain adequate funding for adaptation, COP 7 agreed to establish three new funds. The Special Climate Change Fund under the UNFCCC is to support, inter alia, the implemen�tation of adaptation activities where sufficient information is available, and the Least Developed Countries (LDCs) Fund should support, inter alia, the preparation and implementation of national adaptation programmes of action (NAPAs), which will communicate priority activities addressing the urgent and immediate needs and concerns of the LDCs, relating to adaptation to the adverse effects of climate change. A third fund, the Adaptation Fund, was established under the Kyoto Protocol. Only the Adaptation Fund is yet to become operational. | Adapt-MitigImpacts | 7 - 8 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The climate change process has also adopted the Nairobi Work Programme (NWP), the objective of which is to assist all Parties, in particular developing countries, including LDCs and SIDS, to improve their understanding and assessment of impacts, vulnerability and adaptation, and to make informed decisions on practical adaptation actions. It is also expected that the outcomes of this programme will include enhanced capacity at all levels to select and implement high priority adaptation actions; improved information and advice to the COP; enhanced cooperation among Parties, relevant organ�izations, business, civil society and decision makers; enhanced dissemination of information; and enhanced integration of adaptation with sustainable development. The focus areas of the NWP include: data and observations, methods and tools, climate modelling and downscaling, climate�related risks and extreme events, socio-economic information, adaptation planning and practices, technologies for adaptation research, and economic diversification. | Adapt-MitigImpacts | 8 - 8 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The World Heritage Committee could take advantage of the information and products that have been developed by other organizations through the climate change process. Many international organizations are undertaking considerable work on climate change impacts, vulnerability and adaptation, although not all of it is focused on decisions of the COP. | Adapt-MitigImpacts | 8 - 8 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The impacts of climate change on biodiversity are of major concern to the Convention on Biological Diversity (CBD). At its fifth meeting in 2000, the Conference of the Parties drew attention to the seri�ous impacts of loss of biodiversity on terrestrial and marine ecosystems, and on people’s livelihoods and requested the Convention’s Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) to establish an ad hoc technical expert group which, between 2001 and 2003 carried out an in-depth assessment of the inter-linkages between biodiversity and climate change and its impli�cations for the implementation of the United Nations Framework Convention on Climate Change and its Kyoto Protocol. One of the report’s main findings is that there are significant opportunities for mitigating climate change, and for adapting to climate change while enhancing the conservation of biodiversity. The report also identifies a suite of tools, including the ecosystem approach of the Convention, that can help decision makers to assess the likely impacts and make informed choices when designing and implementing mitigation and adaptation projects. | Adapt-MitigImpacts | 9 - 9 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Statement by Ahmed Djoghlaf, Executive Secretary, Convention on Biological Diversity, delivered to the World Heritage and Climate Change Expert Meeting held at UNESCO, Paris, on 16 and 17 of March 2006 PM_ClimateChange_22 UK 2/05/07 11:55 Page 8<br>9 At its seventh meeting in 2004, the Conference of the Parties to the CBD further requested SBSTTA to develop advice for promoting synergy among activities to address climate change at the national, regional and international level, including activities to combat desertification and land degradation, and activities for the conservation of and sustainable use of biodiversity. Another expert group on biodiversity and adaptation to climate change was then established which undertook a detailed assessment on the integration of biodiversity considerations in the implementation of adaptation activities to climate change. SBSTTA welcomed the report at its eleventh meeting late last year, and requested the expert group to further refine its contents. One of the main findings of the report is that the ability of natural and managed ecosystems to adapt autonomously to climate change is insufficient to arrest the rate of biodiversity loss and that directed adaptation towards increasing ecosystem resilience be promoted. | Adapt-MitigImpacts | 9 - 10 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Collectively, the findings of these two reports provide comprehensive advice and guidance on how to mainstream biodiversity into climate change activities, at the biophysical level and at the level of tools and practical approaches. This information can be applied to the management of protected areas in general, and to World Heritage sites in particular, in order to mitigate and adapt to climate change. The Secretariat of the Convention on Biological Diversity is fully committed to exploring ways and means to enhance its collaboration with the World Heritage Committee on this topic, bearing in mind the challenge we all face to reduce significantly by 2010 the rate of biodiversity loss in the world as a contribution to poverty alleviation and to the benefit of all life on earth. | Adapt-MitigImpacts | 10 - 10 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | World Heritage cultural sites are also exposed to this threat. Ancient buildings were designed for a specific local climate. The migration of pests can have adverse impacts on the conservation of built heritage. Increasing sea level threatens many coastal sites. And the conditions for conservation of archaeological evidence may be degraded in the context of increasing soil temperature. But aside from these physical threats, climate change will impact on social and cultural aspects, with commu�nities changing the way they live, work, worship and socialize in buildings, sites and landscapes, possibly migrating and abandoning their built heritage. | Adapt-MitigImpacts | 11 - 11 |

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| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Several actions can be contemplated in the short term to prevent the impacts of climate change on World Heritage properties, define appropriate adaptation measures, and enhance the sharing of knowledge among stakeholders. Such initiatives should be conducted in close collaboration with relevant bodies already involved in climate change and/or heritage and conservation issues, such as the United Nations Framework Convention on Climate Change (UNFCCC), the Intergovernmental Panel on Climate Change (IPCC), the Convention on Biological Diversity (CBD), the UNESCO Man and the Biosphere programme, the Ramsar Convention on Wetlands and the UNESCO conventions deal�ing with cultural heritage. | Adapt-MitigImpacts | 12 - 12 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The management plans of all sites potentially threatened by climate change should be updated to ensure sustainable conservation of their OUV in this context. The impacts of climate change on World Heritage properties must be assessed through appropriate monitoring and vulnerability assessment processes. Potential mitigation measures at the level of the sites and within the World Heritage network should also be investigated, although mitigation at the global and States Parties level is the mandate of the UNFCCC and its Kyoto Protocol. The importance of climate change threats also justifies the need to implement appropriately tailored risk-preparedness measures. As far as remedial measures are concerned, lessons learnt at several sites worldwide show the relevance of designing and implementing appropriate adaptations measures. The effectiveness of several actions has been demonstrated at a number of sites in the past, such as: increasing the resilience of a site by reducing non-climatic sources of stress, preventively draining a glacial lake to avoid the occur�rence of an outburst flood, improving dykes to prevent coastal flooding and supporting traditional methods to protect a site from sand encroachment. | Adapt-MitigImpacts | 12 - 12 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Strategy to assist States Parties to implement appropriate management responses Preamble: Objectives and requirements Preventive actions Corrective actions: Management, adaptation, and risk management Collaboration, cooperation, and sharing best practices and knowledge Legal issues Conclusion and steps ahead Appendices Expert Meeting of the World Heritage Convention on the Impacts of Climate Change on World Heritage Decision 29 COM 7B.a of the World Heritage Committee, 29th session (2005) Decision 30 COM 7.1 of the World Heritage Committee, 30th session (2006) 4 2 3 PM_ClimateChange_22 UK 2/05/07 11:55 Page 13<br>PM_ClimateChange_22 UK 2/05/07 11:55 Page 14<br>Background 15 Doñana National Park, Spain © Renato Valterza PM_ClimateChange_22 UK 2/05/07 11:55 Page 15<br>Introduction The scientific community now widely agrees on the fact that human activities are disturbing the fragile climatic equilibrium of our planet. The resulting climate change is defined by the United Nations Framework Convention on Climate Change (UNFCCC), in its Article 1, as 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural cli�mate variability observed over comparable time periods'. The UNFCCC thus makes a distinction between 'climate change' attributable to human activities altering the atmospheric composition, and 'climate variability' attributable to natural causes. | Adapt-MitigImpacts | 14 - 17 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | BOX 1 Potential climate change impacts on the Doñana National Park (Spain) 1 The Doñana National Park and World Heritage property, in southern Spain, is the largest and most comprehensive conservation area in Iberia and covers an area of 50,000 hectares. | Adapt-MitigImpacts | 21 - 21 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Potential strategies include investing in focussed research and developing a monitoring system, perhaps with the involvement of the public. Conservation planning should also be integrated with climate risk assessment and a coordinated regional effort should be established to analyse information and assess the risk of biodiversity loss. It is also important to increase the topographic diversity and landscape connectivity of protected areas by creating migratory corridors, to reduce or remove other stresses on the ecosystem and to strengthen risk preparedness, in particular for fires. | Adapt-MitigImpacts | 22 - 22 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The sustainability of this World Heritage site is sensitive to any change in the following climate parameters: sea level rise, sea temperature increase, storm frequency and intensity, precipitation, drought, land run-off, changing oceanic circulation, and ocean acidity. Of central concern are the acute and cumula�tive impacts of coral bleaching, which are triggered when the GBR experiences anomalously high water temperatures. It is important to note, however, that coral bleaching is a major threat to coral reefs every�where. And the threat is not amenable to manage�ment in the short to medium term.6 In 1998 and 2002, major bleaching events occurred in the region. In 2002, between 60 and 95 per cent of corals were affected. Corals of most of the reefs recovered well but a small percentage (less than 5 per cent) of reefs suffered high mortality, losing between 50 and 90 per cent of their corals. As a response, a climate change Response Programme (2004 – 08) was developed to better understand and respond to climate change threats and to prepare an annual Coral Bleaching Response Plan and a climate change Action Plan. The Coral Bleaching Response Plan aims at detecting and measuring bleaching and other short and long term impacts (Satellite imagery, aerial and underwater surveys, community observations) and has received worldwide recognition (and was adapted for the Florida Keys and Indonesia for example). The climate change Action Plan aims at sustaining ecosystems, industries, and communities by identify�ing and implementing relevant management actions, adapting policy and fostering collaborations. | Adapt-MitigImpacts | 23 - 23 |

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|---|---|---|---|---|
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | 22 2 Predicting and managing the impacts of climate change on World Heritage 3. Communication of Martin Parry (Co-chair of working group II of the Intergovernmental Panel on Climate Change) at the expert meeting on Climate Change and World Heritage (UNESCO HQ, Paris, 16-17 March, 2006) 4. Communication of Pablo Dourojeani (the Mountain Institute) at the expert meeting on Climate Change and World Heritage (UNESCO HQ, Paris, 16-17 March, 2006) 5. Communication of Greg Terrill (Assistant Secretary, Heritage Division Australian Department of Environment and Heritage) at the expert meeting on Climate Change and World Heritage (UNESCO HQ, Paris, 16-17 March, 2006) 6. Australian Institute of Marine Science Annual Report 2001-2, p 18 PM_ClimateChange_22 UK 2/05/07 11:55 Page 22 The GBR management actions are recognized as world's best practice7 and that the GBR has relatively low bleaching to date, but further events will be inevitable. The main challenge is to increase broad resilience, which requires multifactor efforts and in many respects adaptation, continuation and enhancement of current efforts. To increase the broad resilience of the GBR Marine Park, in 2004, the GBRMPA increased the percentage of no-take area within the Marine Park from 5% to 33%. Also, the Australian Government is working closely with the Queensland Government on the Reef Water Quality Protection Plan, which aims to halt and reverse the decline in water quality entering the Marine Park by 2013. | Adapt-MitigImpacts | 23 - 24 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | although, to some extent, it also applies to natural heritage properties. 10. Idem PM_ClimateChange_22 UK 2/05/07 11:55 Page 24 25 Predicting and managing the impacts of climate change on World Heritage 2 Climate indicator Atmospheric moisture change Temperature change Sea-level rises Wind Desertification Climate and pollution acting together Climate and biological effects Physical, social and cultural impacts on cultural heritage - pH changes to buried archaeological evidence - Loss of stratigraphic integrity due to cracking and heaving from changes in sediment moisture - Data loss preserved in waterlogged / anaerobic / anoxic conditions - Eutrophication accelerating microbial decomposition of organics - Physical changes to porous building materials and finishes due to rising damp - Damage due to faulty or inadequate water disposal systems; historic rainwater goods not capable of handling heavy rain and often difficult to access, maintain, and adjust - Crystallisation and dissolution of salts caused by wetting and drying affecting standing structures, archaeology, wall paintings, frescos and other decorated surfaces - Erosion of inorganic and organic materials due to flood waters - Biological attack of organic materials by insects, moulds, fungi, inva�sive species such as termites - Subsoil instability, ground heave and subsidence - Relative humidity cycles/shock causing splitting, cracking, flaking and dusting of materials and surfaces - Corrosion of metals - Other combined effects eg. increase in moisture combined with fertilisers and pesticides - Deterioration of facades due to thermal stress - Freeze-thaw/frost damage - Damage inside brick, stone, ceramics that has got wet and frozen within material before drying - Biochemical deterioration - Changes in 'fitness for purpose' of some structures. For example overheating of the interior of buildings can lead to inappropriate alterations to the historic fabric due to the introduction of engineered solutions - Inappropriate adaptation to allow structures to remain in use - Coastal erosion/loss - Intermittent introduction of large masses of 'strange' water to the site, which may disturb the metastable equilibrium between artefacts and soil - Permanent submersion of low lying areas - Population migration - Disruption of communities - Loss of rituals and breakdown of social interactions - Penetrative moisture into porous cultural heritage materials - Static and dynamic loading of historic or archaeological structures - Structural damage and collapse - Deterioration of surfaces due to erosion - Erosion - Salt weathering - Impact on health of population - Abandonment and collapse - Loss of cultural memory - Stone recession by dissolution of carbonates - Blackening of materials - Corrosion of metals - Influence of bio-colonialisation - Collapse of structural timber and timber finishes - Reduction in availability of native species for repair and maintenance of buildings - Changes in the natural heritage values of cultural heritage sites - Changes in appearance of landscapes - Transformation of communities - Changes the livelihood of traditional settlements - Changes in family structures as sources of livelihoods become more dispersed and distant Climate change risk - Flooding (sea, river) - Intense rainfall - Changes in water-table levels - Changes in soil chemistry - Ground water changes - Changes in humidity cycles - Increase in time of wetness - Sea-salt chlorides - Diurnal, seasonal, extreme events (heat waves, snow loading) - Changes in freeze-thaw and ice storms, and increase in wet frost - Coastal flooding - Sea-water incursion - Wind-driven rain - Wind-transported salt - Wind-driven sand - Winds, gusts and changes in direction - Drought - Heat waves - Fall in water table - pH precipitation - Changes in deposition of pollutants - Proliferation of invasive species - Spread of existing and new species of insects (eg. ter�mites) - Increase in mould growth - Changes to lichen colonies on buildings - Decline of original plant materials Table 1. Principal climate change risks and impacts on cultural heritage PM_ClimateChange_22 UK 2/05/07 11:55 Page 25 Survey on the impacts of climate change on World Heritage properties worldwide A questionnaire survey was launched by the World Heritage Centre in 2005 among all States Parties to the World Heritage Convention to assess the extent and nature of the impacts of climate change on World Heritage properties and action taken to deal with such impacts. | Adapt-MitigImpacts | 25 - 27 |

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| UNESCO | Climate Change and World Heritage - UNESCO 2007 | 26 2 Predicting and managing the impacts of climate change on World Heritage Natural Both natural / cultural Cultural 71% 46% 8% Type of sites affected by climate change Coastal and marine sites Glaciers and mountains Terrestrial biodiversity reserves Others 21% 14% 16% 28% Type of biomes for natural World Heritage sites Glacial retreat and melting Sea level rise Loss of biodiversity Species migration Rainfall pattern change and drought Wildffre frequency Coral bleaching Coastal erosion Other 20% 17% 19% 11% 9% 6% 12% Threats of climate change reported for natural World Heritage properties 4% 3% Hurricane and storm frequency Sea level rise Erosion Floods Rainfall pattern change Outdoor painting damage Droughts Other 9% 8% 11% 4% 4% 3% 7% Threats of climate change reported for cultural World Heritage properties 4% PM_ClimateChange_22 UK 2/05/07 11:55 Page 26 Implications for the World Heritage Convention11 Introduction The World Heritage Convention is a unique multilateral environmental agreement as it recognizes that parts of the cultural and natural heritage are of outstanding universal value and therefore need to be preserved as part of the heritage of humankind. The key test for inclusion of cul�tural and natural properties on the World Heritage List is that of meeting the criteria of outstanding universal value (OUV), which are assessed through a rigorous evaluation process by the Advisory Bodies of the World Heritage Convention. Once the properties are inscribed on the World Heritage List they benefit from the World Heritage Convention as an important tool for international cooper�ation; however their conservation and management is the primary responsibility of the State Party where the property is located (Article 4). | Adapt-MitigImpacts | 27 - 28 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Ongoing climate change threats on World Heritage The present and potential future impacts of climate change on biodiversity and ecosystems are well studied and documented. Many of the impacts of climate change mentioned in section 2.1.1 are already being observed, or are expected to occur in the short to medium term, in a number of natural World Heritage sites12. Climate change could amplify and accelerate major existing management problems and threats affecting the integrity of these prop�erties: species and habitat change, resource extraction, inefficient site management, invasive species and, in some cases, armed conflicts. In addition a number of natural World Heritage properties show already high natural sensitivity and low capacity to cope with these social and environmental impacts; which increasingly require the use of innovative adaptive management mechanisms. | Adapt-MitigImpacts | 28 - 28 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | PM_ClimateChange_22 UK 2/05/07 11:55 Page 27 Implementing appropriate management strategies At the same time, extreme weather events, physical and bio�logical changes and increasing pressures from other human activities affect the conditions of integrity of the properties, thus requiring appropriate adaptation and mitigation man�agement. Therefore, should this new management require�ment be considered a prerequisite for a site to meet the conditions of integrity? The integrity required for inscription of natural World Heritage sites might however prove to be an asset when it comes to alleviating climate change impacts through 'healthy' landscapes and seascapes. | Adapt-MitigImpacts | 28 - 29 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The Subsidiary Body for Scientific and Technological Advice (SBSTA) was requested to develop a structured five-year programme of work on impacts, vulnerability and adaptation. The draft list of activities (2006-2008) include methods and tools, data and observations, cli�mate modelling and downscaling, thresholds, socio-eco�nomic data, adaptation practices, research, adaptation platform and economic diversification. | Adapt-MitigImpacts | 29 - 29 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The UNESCO MAB Programme has therefore, together with the Mountain Research Initiative (MRI), launched a project on Global Change in Mountain Regions (GLOCHAMORE) which will attempt to address global change issues by reviewing the state of global change research in selected mountain biosphere reserves. These will then be used as pilot study areas for implementing activities that will help in assessing the impacts of global change on mountain environments and people. The bios�phere reserves selected to take part in the initial stages of the project include a number of World Heritage sites.14 Therefore, the World Heritage Convention and the UNESCO MAB Programme could cooperate and coor�dinate their activities in the field of developing and implementing monitoring, adaptation and mitigation options for World Heritage sites and Biosphere Reserves in mountain ecosystems. | Adapt-MitigImpacts | 30 - 30 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Ramsar Convention on Wetlands (1971) The attention to climate change issues is growing in the framework of the Ramsar Convention15 leading to the Conference of the Parties (COP8, Valencia 2002) and the documents prepared for this including 'Climate Change and Wetlands: Impacts, Adaptation and Mitigation.16 There are plans to update and to look specifically into addi�tional sources of information on wetland ecosystems and species including inland and coastal wetlands as well as peatlands. Resolution VIII.3 which was adopted by the contracting parties states '… that climate change is occurring and may substantially affect the ecological character of wetlands and their sustainable use' and '... | Adapt-MitigImpacts | 30 - 30 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The management challenges include addressing the impacts of multiple pressures where climate change is an added pressure. Wetlands are vulnerable to climate change and have limited adaptive capacity. Therefore innovative solutions are required. Management plans need to consider impacts from climate change and other pres�sures, have to minimize changes in hydrology from other human activities, to reduce non-climate pressures, to mon�itor the changes. Monitoring is essential to look at the effectiveness of adaptation options and steps to rectify any adverse effects should be part of the adaptive manage�ment strategy. A key limitation to implementing adapta�tion and mitigation options for wetlands is the lack of knowledge of wetland hydrology, functioning, their uses and past and present management. Pilot research projects at wetland World Heritage sites, which are also Ramsar sites, could help to fill this gap. | Adapt-MitigImpacts | 30 - 30 |

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| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Contracting Parties to the Ramsar Convention have to manage wetlands to increase their resilience to climate change and variability (extreme climatic events - floods and droughts) and promote wetland and watershed protection and restoration. The Ramsar Convention rec�ognizes that climate change impacts will vary between different wetland types and overall adaptation options are required. Again, the capacity of different regions to adapt to climate change depends upon their current and future states of socio-economic development and their exposure to climate stresses. In general, the potential for adaptation is more limited for developing countries, which are also projected to be more adversely affected by climate change. PM_ClimateChange_22 UK 2/05/07 11:55 Page 29 | Adapt-MitigImpacts | 30 - 30 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | 30 2 Predicting and managing the impacts of climate change on World Heritage Convention on Biological Diversity (CBD) This Convention covers a wide range of issues related to the conservation and sustainable use of biodiversity. The impacts of climate change on biodiversity are already a major concern to the Convention on Biological Diversity. In 2000, the Conference of the Parties (COP) drew attention to the serious impacts of loss of biodiversity on terrestrial and marine ecosystems, and on people's livelihoods and requested the Convention's Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA) to establish an ad hoc technical expert group. This group carried out an in-depth assessment of the inter-linkages between bio�diversity and climate change. There are significant oppor�tunities for mitigating climate change, and for adapting to climate change while enhancing the conservation of bio�diversity. The report also identified tools to help decision makers to assess impacts and make informed choices for mitigation and adaptation projects. | Adapt-MitigImpacts | 30 - 31 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Another expert group on biodiversity and adaptation to climate change was established, which undertook a detailed assessment. One of the main findings is that the ability of natural and managed ecosystems to adapt autonomously to climate change is insufficient to halt the rate of biodiversity loss and that adaptation towards increasing ecosystem resilience should be promoted. If one considers the example of species shifting ranges, although past changes in the global climate resulted in major shifts in species ranges, and biomes, these changes occurred in landscapes that were not as fragmented as today, and with fewer pressures from human activities. Therefore, one of the focus of the CBD includes the creation of corri�dors to protect biodiversity from the effects of climate change, and further, to recognize the important role that protected areas can play in mitigating some of the impacts of climate change. | Adapt-MitigImpacts | 31 - 31 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Networking 'Natural and social systems of different regions have varied characteristics, resources and institutions, and are subject to varied pressures that give rise to differences in sensitivity and adaptive capacity' (Intergovernmental Panel on Climate Change Technical Summary, p.44) This quotation indicates clearly the global impact of climate change. However the challenges need to be addressed at a regional level, with responsibility for adaptation being taken locally. | Adapt-MitigImpacts | 32 - 32 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The schematic below (Figure 1) illustrates the links between impacts, challenges and responses. It suggests that local managers will need to explore the potential for developing or adapting existing management plans and actions to respond to the climate change challenges. | Adapt-MitigImpacts | 32 - 32 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The environmental effects on cultural heritage such as climate change are transboundary. At the very least, regional networks need to be strengthened and focussed on climate change adaptation. UNESCO Regional Offices should encourage and support local initiatives, such as community awareness, emergency preparedness and maintenance training and considering to initiate partner�ships with research-led universities and institutions to ensure that research addresses the climate change prob�lems that cultural heritage is expected Research There is a need for more research on the effects of cli�mate change on both the physical heritage and the social and cultural processes that they are a part of. The Intergovernmental Panel on Climate Change (IPCC), set up in 1988, draws on the work of experts from around the world to provide objective information on climate change for policymakers. Their Assessment Reports provide the technical, scientific and socio-economic information on climate change, possible impacts and responses. Each report includes a Summary for Policy makers. The third Assessment Report was produced in 2001 and the fourth will be published in 2007. | Adapt-MitigImpacts | 32 - 32 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Working Group II of the IPCC is charged with assessing the impact, adaptation and vulnerability of societies to climate change. The report focuses on the effect of climate change on sectors, for example ecosystems, society and settlement and the effects regionally, usually on a continental scale. | Adapt-MitigImpacts | 32 - 32 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Information management, communication, and building public and political support Strengthening of capacity building is important for dealing with effects of climate change as well as for good com�munication and awareness programmes. There is a need to ensure better gathering and analysis of information to identify changing conditions related to climate change. | Adapt-MitigImpacts | 33 - 33 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The notion that all cultural heritage can be saved when confronting climate change must be tackled through information on the meaning and fragility of cultural heritage including adaptation, loss and the notion of abandonment in the face of extreme weather. | Adapt-MitigImpacts | 33 - 33 |

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| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Communication and building public and political support Mobilizing public and political support for climate change adaptation and mitigation inside and outside World Heritage sites is essential. This has to range from local to regional and global approaches and involve a variety of measures: workshops, exhibitions and expositions, media campaigns, audio-visual material and popular publications which link the global phenomenon of climate change to the local and regional context. Most likely, maximum sup�port is further gained through linking local and regional impacts to individual actions and vice versa. For example, simple and straight-forward ways of communicating the impacts and implications of climate change in a local and regional context raised considerable public and political awareness in the Cape Floral Region in South Africa (see Box 2 on p.19) – with subsequent benefits for research, decision-making, planning and management.19 One of the requests of the Committee in its Decision 29 COM 7B.a related to the use of the World Heritage network is 'to demonstrate management actions that need to be taken to meet [climate change] threats both within the properties and in their wider context'. To address this aspect of the Decision, it is proposed that spe�cific World Heritage sites be used as demonstration mod�els for countries and other stakeholders to design adaptation and mitigation strategies for World Heritage sites facing climate change challenges. Communication on this issue could occur at two levels. First, at the local and regional level where World Heritage sites are used as anchors to build site-based and national awareness and strategies (bringing together NGO's, academics, and other field-based researchers). At the second, global level, the newly developed strategies are disseminated to the World Heritage Committee, States Parties and other stakeholders through NGO networks (Advisory Bodies and other con�servation NGOs), academic networks and UN bodies. | Adapt-MitigImpacts | 33 - 33 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Local communities should be closely involved in the processes of investigation of the impacts of climate change and the development of adaptation strategies. The strong links between cultural and natural heritage could also be reflected in these case studies. These case studies should also be the opportunity to illustrate how adaptation meas�ures could be developed to avoid the general feeling of dis�couragement of the public in the face of climate change. | Adapt-MitigImpacts | 34 - 34 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | PM_ClimateChange_22 UK 2/05/07 11:55 Page 33<br>34 2 Predicting and managing the impacts of climate change on World Heritage A two-pronged approach is required: first, the vulnerabil�ity of natural World Heritage sites, which are particularly at risk, should be assessed by the States Parties and specific site-level mitigation and adaptation strategies should be designed and implemented in partnership with relevant stakeholders. Second, States Parties and site managers need to look beyond the individual site level and develop and implement regional and/or transboundary mitigation and adaptation strategies that reduce the vulnerability of natural World Heritage sites in a larger landscape or seascape context. Natural World Heritage sites must be seen as core sites within functioning regional networks of protected areas, conservation corridors and stepping stones. 'Healthy' World Heritage sites can contribute con�siderably to 'healthy' landscapes and seascapes that are better able to buffer climate change impacts. The World Heritage Centre and Advisory Bodies to the World Heritage Convention should encourage States Parties and site managers, in collaboration with relevant academic and research institutions, to accomplish these tasks and make available their knowledge and experience in the field of climate change adaptation and mitigation. | Adapt-MitigImpacts | 34 - 35 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Assess future climate change scenarios through appropriate tools and guidelines A comprehensive set of technical guidelines to assess cli�mate change impacts and response strategies in general is available from the Intergovernmental Panel on Climate Change,24,25 and has been reviewed from a coastal per�spective.26 Climate change impacts and response strate�gies have been recently discussed in detail for islands.27 22. For a detailed discussion see Schröter et al. (2005, Assessing vul�nerabilities to the effects of global change: an eight step approach. Mitigation and Adaptation Strategies for Global Change 10, 573-596). According to them, for vulnerability assessments, the role of numerical modelling is the projection of future states of a system. Here, steps 1-3 take place prior to modelling, whereas steps 4-8 take place as part of the modelling and modelling refinement process. | Adapt-MitigImpacts | 35 - 35 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Risk and vulnerability maps No one can afford to wait for all the research to be com�pleted for guidance on the management of cultural her�itage under climate change conditions. It will be important to produce risk and vulnerability maps of World Heritage regions and sub-regions which overlay climate data and heritage site locations so that an overview of the risks to different aspects of cultural heritage can be obtained. Using this information, detailed adaptation strategies can then be developed. | Adapt-MitigImpacts | 36 - 36 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Applying adaptive management responses In many areas, promising management responses are being developed and implemented already. A number of different solutions to specific problems posed by climate change are available. Technical solutions are available in some cases, but they might not be affordable or feasible in all cases, and they might also be controversial when it comes to application to World Heritage sites, with poten�tial impacts on the conditions of integrity. For example, in some coastal areas, reinforcing dykes and drains to deal with rising sea level have been considered as options, whereas in other coastal areas, management has favoured a planned retreat of settlements from low-lying areas. The water level of some wetlands can be con�trolled by regulating water inflow or outflow with dams, but increasing temperatures and decreasing precipitation will in many areas result in stiffer competition between nature and people for water. | Adapt-MitigImpacts | 37 - 37 |

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| UNESCO | Climate Change and World Heritage - UNESCO 2007 | BOX 10 Reducing the risk of GLOF in the Sagarmatha National Park (Nepal)33 The Tsho Rolpa glacial lake project is one of the most significant examples of collaborative anticipatory plan�ning by the government, donors, and experts in GLOF mitigation. Tsho Rolpa was estimated to store approxi�mately 90-100 million m3, a hazard that called for urgent attention. A 150-meter tall moraine dam held the lake, which if breached, could cause a GLOF event in which a third or more of the lake could flood down�stream. This threat led to a collaborative action by the Nepalese Government and the Netherlands Development Agency, with the technical assistance of Reynolds Geo-Sciences Ltd., supported by the United Kingdom Department for International Development. | Adapt-MitigImpacts | 37 - 37 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | From this box it is particularly important to stress that realistic response strategies cannot be planned without taking into account the impacts from other non-climatic stresses on natural ecosystems, such as habitat frag�mentation and loss, alien and invasive species, over�exploitation, pollution, sedimentation, etc which severely impede natural adaptation and mitigation strategies. Hence, there is a need for the World Heritage Convention to continue enhancing its work in assessing the management and conditions of integrity of World Heritage properties, both through reactive monitoring and periodic reporting. | Adapt-MitigImpacts | 38 - 38 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Monitoring and adaptative management Monitoring the impact of climate change is obviously an important issue, as was mentioned in the sections on 'research' and 'information management'. But the care�ful monitoring of adaptive management measures must also be planned in the context of climate change and World Heritage. | Adapt-MitigImpacts | 38 - 38 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Monitoring climate, climate impacts and management responses is critical. Only then will one be able to tell which responses do work and which do not. But few of the existing monitoring measures are tailored to issues relevant to climate change adaptation and mitigation of 37 Predicting and managing the impacts of climate change on World Heritage 2 34. Shafer, 1999. National park and reserve planning to protect bio�logical diversity: some basic elements. Landscape and Urban Planning 44, 123-153. | Adapt-MitigImpacts | 38 - 38 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | PM_ClimateChange_22 UK 2/05/07 11:55 Page 37<br>38 2 Predicting and managing the impacts of climate change on World Heritage protected areas. Capacity-building, for example in rela�tion to fire and risk management, is underway in many areas, sometimes already linked to the additional prob�lems posed or accelerated by climate change. In many cases, adaptive management, if implemented properly, should help to buffer climate change impacts. Adaptive management is a systematic process of continually improving policies and practices by learning from the results of previous actions. | Adapt-MitigImpacts | 38 - 39 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Experience and lessons learned on addressing climate change impacts stress the need for using a number of management responses at national and local levels. The World Heritage Convention provides an opportunity to develop strategies to implement relevant actions in respect of cultural and natural heritage properties threatened by climate change. Given the complexity of this issue, States Parties may request guidance from the World Heritage Committee to implement appropriate management responses to face the threats posed by climate change on their natural and cultural properties inscribed on the World Heritage List. | Adapt-MitigImpacts | 41 - 41 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Therefore, the main objective of this strategy is to review the main topics that should be considered when preparing to implement preventive and/or corrective management responses to deal with the adverse impacts of climate change. | Adapt-MitigImpacts | 41 - 41 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Conservation is the management of change, and climate change is one of the most significant global challenges facing society and the environment today. The actions that need to be taken to safeguard heritage are threefold: a. Preventive actions: monitoring, reporting and mitiga�tion of climate change effects through environmentally sound choices and decisions at a range of levels: indi�vidual, community, institutional and corporate. | Adapt-MitigImpacts | 41 - 41 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Lastly, climate change is one risk among a number of chal�lenges facing World Heritage sites. This threat should be considered in the broader context of the conservation of these sites. | Adapt-MitigImpacts | 41 - 41 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Mitigation** The UNFCCC is the UN instrument through which mitiga�tion strategies at the global and States Parties level is being addressed. However, the World Heritage community could participate in climate change mitigation at the level of the World Heritage through: a. Global level actions (World Heritage Convention): i. Provide information to IPCC and UNFCCC on the impacts of climate change on World Heritage sites to assist them in tailoring mitigation strategies. | Adapt-MitigImpacts | 41 - 41 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Corrective actions: Management, adapta�tion, and risk management* The States Parties need to be aware of the risks posed by climate change and that clear short term actions are needed and possible: a. Global level actions (World Heritage Convention): i. Include climate change as an additional source of stress in the Strategy for reducing risks from disasters at World Heritage properties which is presented as a separate working Document (WHC-06/30.COM/7.2), including approaches to vulnerability assessment. | Adapt-MitigImpacts | 42 - 42 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | ii. Request new and existing sites to integrate climate change issues into new and revised management plans (as appropriate) including: risk preparedness, adaptive design and management planning. | Adapt-MitigImpacts | 42 - 42 |

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| UNESCO | Climate Change and World Heritage - UNESCO 2007 | PM_ClimateChange_22 UK 2/05/07 11:55 Page 41<br>42 3 Strategy to assist States Parties to implement appropriate management responses iv. Develop communication strategies taking advantage of the World Heritage global network to inform the public and policy makers about the impacts of cli�mate change on World Heritage sites and build pub�lic and political support for actions to address the situation. | Adapt-MitigImpacts | 42 - 43 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | ii. Ensure that training courses on risk assessments, reporting, adaptation and monitoring are coordi�nated with other international institutions, Advisory Bodies, and secretariats of other conventions. | Adapt-MitigImpacts | 43 - 43 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | c. State Party / site level actions: i. Provide information to decision-makers, stakehold�ers, local communities, users of the sites, site man�agers, and other heritage specialists about the impacts of climate change on sites, management responses, possible assistance, existing networks, specific training, courses, and long- distance learn�ing opportunities. | Adapt-MitigImpacts | 43 - 43 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Legal issues After having considered the range of actions to be under�taken in the framework of the management of climate change impacts on World Heritage, the group of experts considered that when the Operational Guidelines are next revised, the possibility of including climate change related aspects could be explored. | Adapt-MitigImpacts | 43 - 43 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | While opportunities are being explored with donors for implementing pilot projects on vulnerability assessment and adaptation at some World Heritage sites, the impacts of climate change can be effectively addressed only when the strategy outlined in this publication is applied at the field level. It is for this purpose that the World Heritage Committee has requested States Parties and all partners concerned to implement this strategy to protect the out�standing universal values, integrity and authenticity of World Heritage sites from the adverse effects of climate change, to the extent possible and within the available resources. | Adapt-MitigImpacts | 45 - 45 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | 4 Conclusion and steps ahead 44 PM_ClimateChange_22 UK 2/05/07 11:55 Page 44<br>45 Chinguetti mosque, Mauritania © UNESCO / Galy Bernard Appendices PM_ClimateChange_22 UK 2/05/07 11:55 Page 45<br>Expert Meeting of the World Heritage Convention on the Impacts of Climate Change on World Heritage The World Heritage Committee at its 29th session (Durban, 2005) requested the World Heritage Centre (WHC), in collaboration with the Advisory Bodies, inter�ested States Parties and petitioners who had drawn the attention of the Committee to this issue, to convene a broad working group of experts on the impacts of climate change on World Heritage (Decision 29 COM 7B.a). The Committee took this decision noting 'that the impacts of climate change are affecting many and are likely to affect many more World Heritage properties, both natural and cultural in the years to come'. The Committee requested the broad working group of experts to: • review the nature and scale of the risks posed to World Heritage properties arising specifically from climate change; • jointly develop a strategy to assist States Parties to imple�ment appropriate management responses; and • prepare a joint report on 'Predicting and managing the effects of climate change on World Heritage' to be examined by the Committee at its 30th session (Vilnius, 2006). | Adapt-MitigImpacts | 45 - 47 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The meeting was prepared after a rigorous and extensive consultation process between a core group, comprising the World Heritage Centre, the Advisory Bodies, and experts from the State Party of the United Kingdom. The United Nations Foundation (UNF) provided crucial financial support to the World Heritage Centre to enable some of the preparatory and follow-up actions. The agenda, list of participants and background documents for the expert meeting were prepared through collaboration between the core group. A background document compiled information on the assessment and management of the impacts of climate change in the context of World Heritage. A number of case studies on the impacts of climate change on specific World Heritage sites were also submitted by many experts for consideration by the participants to the meeting. | Adapt-MitigImpacts | 47 - 47 |

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| UNESCO | Climate Change and World Heritage - UNESCO 2007 | PM_ClimateChange_22 UK 2/05/07 11:55 Page 46<br>47 Appendices 16 March 2006 09.00 Registration 09.15 – 10.00 Session 1 Opening Session Chair: Mr Francesco Bandarin (Director of the WHC) Rapporteur: Dr Mechtild Rössler (Chief Europe and North America WHC) Welcome Mr Francesco Bandarin (Director of the WHC) Opening remarks Ms Ina Marciulionyte (Chairperson of the WH Committee) Keynote address on 'Implications of climate change Mr Martin Parry for World Heritage sites' (Co-chair of WGII of the IPCC) Overview of the decision of the World Heritage Mr Kishore Rao Committee, the agenda, the objectives of the meeting, (Deputy Director of the WHC) the strategic requirements and report on the results of the climate change survey submitted to States Parties 10.00 – 10.30 Coffee break 10.30 – 13.00 Session 2 Natural Heritage Chair: Mr David Sheppard (Head of IUCN's Programme on Protected Areas) Rapporteur: Mr Guy Debonnet (WHC) 2-5 min Convention on Biological Diversity Statement on behalf of Mr Ahmed Djoghlaf (Executive Secretary of the CBD) 10 min Key issues for climate change and wetlands Dr Habiba Gitay (on behalf of Ramsar Convention) (World Resources Institute) 10 min United Nations Framework Convention Mr Festus Luboyera on Climate Change (UNFCCC Secretariat) 10 min UNESCO Man and the Biosphere Programme Dr Natarajan Ishwaran (UNESCO, Division of Ecological and Earth Sciences) 35 min Case Study 1: 'Towards conservation strategies for Mr Guy Midgley and Mr Bastian Bomhard future climate change in the Cape Floral Region [presenting author] (South African National Protected Areas (South Africa)' Biodiversity Institute) 35 min Case Study 2: The Great Barrier Reef (Australia) Dr Greg Terrill (Australian Department of Environment and Heritage) 35 min Case Study 3: 'Risks, points of view and conflicts Mr Pablo Dourojeani in the Huascarán NP World Heritage site (Peru) due (The Mountain Institute, Peru) to climate change' 13.00 – 14.00 Lunch Break Agenda of the Expert Meeting on Climate Change and World Heritage Special Expert Meeting of the World Heritage Convention: Climate Change and World Heritage UNESCO HQ, Paris (France) 16-17 March, 2006 16 March 2006 ... | Adapt-MitigImpacts | 47 - 48 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | PM_ClimateChange_22 UK 2/05/07 11:55 Page 49<br>50 Appendices Decision 29 COM 7B.a of the World Heritage Committee, 29th session (2005) The World Heritage Committee, 1. Having examined Document WHC-05/29.COM/7B.Rev and the draft Decision 29 COM 7B.a.Rev, 2. Recognizing the work being undertaken within the framework of the UN Convention on Climate Change (UNFCC), and the need for a proper coor�dination of such work with the activities under the Convention, 3. Takes note of the four petitions seeking to have Sagarmatha National Park (Nepal), Huascaran National Park (Peru), the Great Barrier Reef (Australia) and the Belize Barrier Reef Reserve System (Belize) included on the List of World Heritage in Danger, 4. Appreciates the genuine concerns raised by the various organizations and individuals supporting these petitions relating to threats to natural World Heritage properties that are or may be the result of climate change, 5. Further notes that the impacts of climate change are affecting many and are likely to affect many more World Heritage properties, both natural and cultural in the years to come, 6. Encourages all States Parties to seriously consider the potential impacts of climate change within their management planning, in particular with monitoring, and risk preparedness strategies, and to take early action in response to these potential impacts; 7. Requests the World Heritage Centre, in collabora�tion with the Advisory Bodies, interested States Parties and petitioners, to establish a broad work�ing group of experts to: a) review the nature and scale of the risks posed to World Heritage proper�ties arising specifically from Climate Change; and b) jointly develop a strategy to assist States Parties to implement appropriate management responses, 8. Welcomes the offer by the State Party of the United Kingdom to host a meeting of such work�ing group of experts, 9. Requests that the working group of experts, in consultation with the World Heritage Centre, the Advisory Bodies and other relevant UN bodies, prepare a joint report on 'Predicting and managing the effects of climate change on World Heritage', to be examined by the Committee at its 30th session (2006), 10. Strongly encourages States Parties and the Advisory Bodies to use the network of World Heritage properties to highlight the threats posed by climate change to natural and cultural heritage, start identifying the properties under most serious threats, and also use the network to demonstrate management actions that need to be taken to meet such threats, both within the properties and in their wider context, 11. Also encourages UNESCO to do its utmost to ensure that the results about climate change affecting World Heritage sites reach the public at large, in order to mobilize political support for activities against climate change and to safeguard in this way the livelihood of the poorest people of our planet. | Adapt-MitigImpacts | 50 - 51 |

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| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Decision 30 COM 7.1 of the World Heritage Committee, 30th session (2006) The World Heritage Committee, 1. Having examined Document WHC-06/30.COM/7.1, 2. Recalling Decision 29 COM 7B.a adopted at its 29th session (Durban, 2005), 3. Also recalling the submission in 2005 of four peti�tions by civil society and non-governmental organ�izations on the impacts of Climate Change on World Heritage properties, complemented by an additional petition in February 2006, 4. Further recalling paragraph 44 of the Operational Guidelines, 5. Thanks the Government of the United Kingdom for having funded the meeting of experts, which took place on the 16th and 17th of March 2006 at UNESCO Headquarters in Paris, and also thanks the United Nations Foundation for its support, as well as all the experts who contributed to the meeting, 6. Endorses the 'Strategy to assist States Parties to implement appropriate management responses' described in Document WHC-06/30.COM/7.1, and requests the Director of the World Heritage Centre to lead the implementation of the 'Global PM_ClimateChange_22 UK 2/05/07 11:55 Page 50 51 Appendices level actions' described in the Strategy through extrabudgetary funding and also takes note of the report on 'Predicting and managing the impacts of Climate Change on World Heritage', 7. Encourages UNESCO, including the World Heritage Centre, and the Advisory Bodies to dis�seminate widely this strategy, the report, and any other related publications through appropriate means to the World Heritage community and the broader public, 8. Requests States Parties and all partners concerned to implement this strategy to protect the Outstanding Universal Value, integrity and authen�ticity of World Heritage sites from the adverse effects of Climate Change, to the extent possible and within the available resources, recognizing that there are other international instruments for coordinating the response to this challenge, 9. Invites States Parties, the World Heritage Centre and the Advisory Bodies to build on existing Conventions and programmes listed in Annex 4 of Document WHC-06/30.COM/7.1, in accordance with their mandates and as appropriate, in their implementation of Climate Change related activities, 10. Also requests States Parties, the World Heritage Centre, and the Advisory Bodies to seek ways to integrate, to the extent possible and within the available resources, this strategy into all the rele�vant processes of the World Heritage Convention including: nominations, reactive monitoring, peri�odic reporting, international assistance, capacity building, other training programmes, as well as with the 'Strategy for reducing risks from disasters at World Heritage properties' (WHC- 06/30.COM/7.2), 11. Strongly encourages the World Heritage Centre and the Advisory Bodies in collaboration with States Parties and other relevant partners to develop proposals for the implementation of pilot projects at specific World Heritage properties espe�cially in developing countries, with a balance between natural and cultural properties as well as appropriate regional proposals, with the objective of developing best practices for implementing this Strategy including preventive actions, corrective actions and sharing knowledge, and recommends to the international donor community to support the implementation of such pilot projects, 12. Further requests the States Parties and the World Heritage Centre to work with the Intergovernmental Panel on Climate Change (IPCC), with the objective of including a specific chapter on World Heritage in future IPCC assessment reports, 13. Requests the World Heritage Centre to prepare a policy document on the impacts of climate change on World Heritage properties involving consulta�tions with relevant climate change experts and practitioners of heritage conservation and man�agement, appropriate international organizations and civil society, to be discussed at the General Assembly of States Parties in 2007. A draft of the document should be presented to the 31st session in 2007 for comments. | Adapt-MitigImpacts | 51 - 52 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The fact that climate change poses a threat to the outstanding universal values of World Heritage sites has several implications for the 1972 Convention. Lessons learnt at some sites show the relevance of designing and implementing appropriate adaptations measures. Research at all levels would also have to be promoted in collaboration with the various bodies involved in climate change work, especially for cultural heritage where the level of involvement of the scientific community needs to be enhanced. | Adapt-Mitig | 4 - 4 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | In the area of technology transfer, the UNFCCC secretariat has prepared a number of reports which are directly or partially relevant to adaptation, including technical papers on: coastal adaptation technologies, and enabling environments with specific references to adaptation technologies. | Adapt-Mitig | 7 - 7 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | In addition, the secretariat has established a technology information system (TT:CLEAR) which includes following elements relating to adaptation: inventory of existing adaptation centres; adap�tation technology projects (mainly from national communications of both Annex I and non-Annex I Parties); and an adaptation technologies database. | Adapt-Mitig | 7 - 7 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The secretariat is facilitating Parties to undertake capacity-building activities related to the needs for vulnerability and adaptation assessment and implementation of adaptation measures in devel�oping countries and countries with economies in transition. Furthermore efforts are underway to develop a web-based information clearing house that would support networking and partnership activities between Parties, intergovernmental organizations and non-governmental organizations, and to promote informal exchanges of information on actions relating to education, training and public awareness. | Adapt-Mitig | 7 - 7 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | In this scenario, the conservation of World Heritage natural sites may be jeopardized. Increased ocean temperature and acidification pose a threat to marine biodiversity. Many marine World Heritage sites are tropical coral reefs whose exposure to bleaching events is increasing, possibly leading to massive extinction of coral reefs. The increase of atmospheric temperature is also lead�ing to the melting of glaciers worldwide (in both mountainous and Polar Regions). Lastly, terrestrial biodiversity may also be affected with species shifting ranges, changes in the timing of biological cycles, modification of the frequency and intensity of wildfires, migration of pests and invasive species, etc. | Adapt-Mitig | 11 - 11 |

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| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The Intergovernmental Panel on Climate Change (IPCC) states in its Third Assessment Report that 'The Earth's climate system has demonstrably changed on both global and regional scales since the pre�industrial era, with some of these changes attribut�able to human activities'. To limit the amplitude of climate change, mitigation (reducing the emission and enhancing the sinks of greenhouse gases) is needed, but the same report mentions that 'adapta�tion is a necessary strategy at all scales to comple�ment climate change mitigation efforts'. | Adapt-Mitig | 17 - 17 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | And second, because appropriate management responses consist in a 'no regret-policy' since efforts to reduce the vulnerability and increase the resilience of sites to existing non-climatic pressures and threats would also reduce their vulnerability to climate change related stresses. | Adapt-Mitig | 17 - 17 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The Thames Barrier can go to 2025 before the 1000 year return flood event is exceeded. World Heritage site managers need to engage in the wider planning processes for a new Thames Barrier, in flood management planning for London and in develop�ment and land-use planning. The Management Plans of World Heritage sites should incorporate climate change adaptation in their guiding principles for management over the next 25-30 years and in the quinquennial revision of the management objectives. | Adapt-Mitig | 25 - 25 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Implications in the context of the World Heritage Convention In the specific context of the World Heritage Convention, climate change raises many concerns that are of critical nature for the future implementation of the World Heritage Convention. Natural World Heritage sites are inscribed on the World Heritage List if they meet one or more of the criteria of outstanding universal value and also meet the conditions of integrity13. At present, if a site is threatened by serious and specific danger – both ascer�tained and/or potential danger – it can be inscribed in the List of World Heritage in Danger (paragraph 180, Operational Guidelines). The World Heritage Convention also notes that if a property loses the characteristics which warranted its inscription on the World Heritage List it can be deleted from the List (paragraph 176(e), Operational Guidelines). Furthermore the States Parties of the World Heritage Convention have the duty of ensuring the pro�tection, conservation and transmission to future genera�tions of the properties located on its territory (Article 4). | Adapt-Mitig | 28 - 28 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | • Should the World Heritage Convention – and its associ�ated Operational Guidelines seriously consider the fact that for some natural properties it will be impossible to maintain the 'original' OUV values for which they were originally inscribed on the World Heritage List, even if effective adaptation and mitigation strategies are applied; therefore requiring an 'evolving' assessment of OUV values? | Adapt-Mitig | 28 - 28 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The Programme of work (Buenos Aires) requested further implementation of actions including: • data and modelling, vulnerability and adaptation assess�ment and implementation; • that the Global Environment Facility report on support of the programme; • that the UNFCCC secretariat organize regional work�shops to facilitate information exchange and integrated assessments on adaptation reflecting regional priorities. | Adapt-Mitig | 29 - 29 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | In the meantime three new funds have been established, a data base on local coping strategies was made available, capacity-building frameworks have been agreed on, a Consultative Group of Experts (CGE) has developed hands�on training materials and a seminar on the development and transfer of technologies for adaptation took place in June 2005. | Adapt-Mitig | 29 - 29 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | A major component of adaptation that needs further attention is the assessment of the vulnerability of wetlands to climate change. Many wetlands are vulnerable to climate change either due to their sensitivity to changes in hydrological regimes and/or due to the other pressures from human activities. | Adapt-Mitig | 30 - 30 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | In 2004, the 7th COP (Kuala Lumpur, 2004) promoted syn�ergy among the activities to address climate change, including desertification and land degradation, conserva�tion, sustainable use of biodiversity, and the development by 2010 of national-level conservation strategies that are specifically designed to be resilient to climate change. | Adapt-Mitig | 31 - 31 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Designing management plans accounting for the issue of climate change If a Management Plan is specifically designed and format�ted to foster its use as a working document which can be updated on a regular basis, then it can become a key tool in the effective stewardship of World Heritage sites under threat from climate change and actions in response to cli�mate change can be flexibly introduced throughout the document. | Adapt-Mitig | 31 - 31 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The following specific actions to adapt to climate change might be necessary at a regional or local level to ensure a continuous redefinition of adaptation strategies as climate projections are refined: • Enhancement of appropriate education and traditional skills. | Adapt-Mitig | 31 - 31 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | • Training on the various problems and possible responses to climate change in all aspects of conservation activity namely, development of traditional skills, monitoring, management and emergency preparedness. | Adapt-Mitig | 31 - 31 |

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| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Level of actions (site, local, landscape, State Party, regional or thematic, global level) and networking Involvement of local communities A strong focus also needs to be put on local knowledge sys�tems and the way that they understand and adapt to changes in climate. Communities need to be a part of the overall process of understanding and dealing with climate change (e.g. as mentioned in the case studies on the Huascarán National Park, see Box 4 on p.17). Local influen�tial sectors should also be part of this process such as tourism (e.g. in the Great Barrier Reef region, see Box 5 on p.17), or industry (such as mining in the Huascarán National Park, see Box 4 on p.17). This participation would include management planning and implementation, monitoring, and so on. | Adapt-Mitig | 31 - 31 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Information management Scientific understanding of traditional materials and assemblies is the foundation of sustainable management of World Heritage sites in a changing climate (including rain penetration, high summer temperatures and chloride loading). Information based on cross-field monitoring need to be sensitive to the scale and time of problems and guidance must be designed accordingly. | Adapt-Mitig | 33 - 33 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Subsequently, these case studies could be used as field experimental pilot sites for the development of appropri�ate strategies. From these examples a number of key prin�ciples can be derived on which sustainable adaptive responses to climate change can be developed. These principles are: • To ensure that the development of education and the teaching of traditional skills is adapted to the needs of a changing environment; • To undertake rigorous ongoing scientific monitoring of changes in condition of cultural heritage materials; • To recognize that maintenance measures will be tested more severely due to climate change and may require a greater proportion of available resources; • To design flexible management planning objectives to enable priorities to be re-evaluated in response to climate change; • To carry out scientific research to develop understand and knowledge of historic and archaeological materials to support local/regional decision-making and to place cultural values and significance in their social/environ�mental context. | Adapt-Mitig | 34 - 34 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Cultural heritage Regional and thematic approach Regional strategies provide a link between global climate change initiatives and local management plans since cli�mate change data is based on regional scenarios. It is therefore appropriate to build on relevant available infor�mation and to create information of common interest to World Heritage sites in a region. A regional strategy could, for example, interpret IPCC data to make them rel�evant to the local situation; it could promote the creation of vulnerability maps for the region and sub regions and it could provide guidance on the monitoring programmes that might be appropriate for World Heritage sites in the region which might be affected differently by different climate change parameters. Thematic groupings of sites likely to face similar threats such as archaeological, mov�able, coastal, mountainous or marine sites, could also be developed. | Adapt-Mitig | 36 - 36 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Local approach The obligation under the World Heritage Convention to develop management systems for World Heritage sites provides an opportunity to integrate climate change adaptation measures in the process. Documents such as management plans should include a statement of the objectives necessary for the long term preservation of the World Heritage sites and its landscape setting, aiming to balance the interests of conservation, public access, and the interests of those who live and work in the area. The objectives could be based on: • Identification of the outstanding values of the World Heritage site including the reasons that make the World Heritage site special and justification for its inscription as a World Heritage site. However, the pro�tection of World Heritage site values and sympathetic land management within the area greatly depends on identifying and resolving key management issues. | Adapt-Mitig | 36 - 36 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | • An assessment of why the World Heritage site is sensi�tive and vulnerable to the pressures of climate change including objectives for the management of the World Heritage site based on a strategic view over 20, 25 or 30 years, and medium-term objectives for 5 to 10 years. | Adapt-Mitig | 36 - 36 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | • Wireless communication adaptation of wireless proto�cols to building and site sensors such as infestation sur�veying equipment. | Adapt-Mitig | 37 - 37 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Adaptation Natural heritage There is a need to better link World Heritage properties with corridors and conservation-friendly land/water uses in the framework of wider landscapes/seascapes plan�ning and management. | Adapt-Mitig | 37 - 37 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Response strategies that enable protected areas and pro�tected-area networks to adapt to climate change stress the importance for approaches beyond the individual site level.31,32 World Heritage sites are largely isolated from each other, fall in very different biogeographical and political entities, and do not share common management systems or structures. Faced with climate change, World Heritage sites must be considered in the context of the surrounding matrix of other land uses and protected areas. In most cases, response strategies for successful adaptation that do not recognize this need will fail. | Adapt-Mitig | 37 - 37 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Adaptation to glacier melting in mountainous areas is limited to reducing the threat posed by Glacial Lake Outburst Floods (GLOF) events by preventive lake drain�ing as was conducted in the Sagarmatha National Park in 1998-2002 (see Box 10 below). | Adapt-Mitig | 37 - 37 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Mitigation Mitigation consists in an anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases. The UN Framework Convention on Climate Change is the preferred international tool to address mitigation at the global and States Parties levels. | Adapt-Mitig | 38 - 38 |

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| UNESCO | Climate Change and World Heritage - UNESCO 2007 | However, some mitigation opportunities could be contemplated in the context of the World Heritage Convention at the level of the World Heritage sites. | Adapt-Mitig | 38 - 38 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | Second, the World Heritage Centre oversees a number of conservation projects aiming at restoring degraded habitats in natural World Heritage sites. Such activities indirectly contribute to the improvement of carbon sequestration and this could be quantified in more details. | Adapt-Mitig | 38 - 38 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | To keep a realistic perspective, we must be aware that the total carbon dioxide sequestrated in World Heritage sites is probably limited because of the relatively limited area concerned. The benefit of mitigation at World Heritage sites is therefore likely to be negligible on a quantitative basis. Nevertheless, considering the iconic character of the World Heritage sites and the powerful communica�tion tool of the World Heritage network, it would be most useful in terms of best practices advertising. | Adapt-Mitig | 38 - 38 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | • A range of responses to climate change are defined by the sites. They may differ between cultural heritage sites and natural heritage sites. Responses may include monitoring, maintaining, managing and/or carrying out further research – all within the framework pro�vided by a site's management system. At this point best practice solutions may be considered. | Adapt-Mitig | 39 - 39 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | What do we need to do for cultural heritage? (Monitor, maintain, research etc.) START HERE END HERE What do we need to do for natural heritage? (Management etc.) Choose site Describe evidence Deffne responses Develop Best Practice of climate change to climate change Figure 2: Process response to climate change. | Adapt-Mitig | 39 - 39 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | b. Corrective actions: adaptation to the reality of climate change through global and regional strategies and local management plans. | Adapt-Mitig | 41 - 41 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | c. State Party / site level actions: i. Encourage site managers, to the extent possible and within the available resources, to monitor relevant climate parameters and to report on adaptation strategies. | Adapt-Mitig | 41 - 41 |
| UNESCO | Climate Change and World Heritage - UNESCO 2007 | The very significant challenges which climate change poses to World Heritage sites can not be effectively dealt with by any one organization. It calls for a collective response and the World Heritage Convention, which pro�motes international cooperation for heritage conservation, can be an effective mechanism for mobilizing such support from relevant organizations, conventions and processes. | Adapt-Mitig | 45 - 45 |
| UNESCO | Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | Coral reefs are ecologically and economically important ecosystems found across the world's tropical and sub-tropical oceans. Despite covering less than 0.1% of the ocean floor, reefs host more than one quarter of all marine fish species (in addition to many other marine animals)1,2. They are the most inherently biodiverse ecosystems in the ocean – comparable to rainforests on land. These 'Rainforests of the Sea' provide social, economic and cultural services with an estimated value of over USD $1 Trillion globally3,4. For example, the complex three-dimensional structure of reefs not only provides habitat but also dissipates wave energy to protect coastlines from erosion and damage. Coastal protection and human use (including tourism, recreation and fishing) supply the greatest economic benefits from coral reefs to over half a billion people around the world. | Adapt-MitigImpacts | 3 - 3 |
| UNESCO | Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | These impacts lead to reduced habitat for marine organisms that depend upon the reef ecosystem, and fewer ecosystem goods and services, such as food, income and coastal protection, for dependent human communities. | Adapt-MitigImpacts | 3 - 3 |
| UNESCO | Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | LOCAL MANAGEMENT IS NO LONGER SUFFICIENT TO ENSURE THE FUTURE OF CORAL REEFS. PROTECTING WORLD HERITAGE REEFS REQUIRES COMPLEMENTARY NATIONAL AND GLOBAL EFFORTS TO LIMIT WARMING TO 1.5°C © The Ocean Agency, XL Catlin Seaview Survey, Christophe Bailhache Great Barrier Reef, Wilson Reef<br>10 Impacts of Climate Change on World Heritage Coral Reefs Until now, the focus for World Heritage sites in maintaining the Outstanding Universal Value of their key features has been on maintaining integrity through on-site management and pressures, and national or regional enabling legislation. Efforts to restore resilience and reduce local human stressors remain necessary but are no longer sufficient. For the first time, a ubiquitous global threat - heat stress sufficient to cause frequent severe bleaching and mortality - now threatens the OUV of World Heritage sites in a way that cannot be resolved through local management alone. The only viable solution is for all countries with World Heritage coral reefs to not only act to reduce local stressors but also to reduce their greenhouse gas emissions to net zero, along with supporting active $CO_2$ removal from the atmosphere and upper ocean. | Adapt-MitigImpacts | 11 - 12 |

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| UNESCO | Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | 6. Additional Research This analysis provides a first scientific assessment of past impacts on World Heritage coral reefs and the risks under different emissions scenarios in coming decades. Further work to strengthen and provide a more comprehensive analysis to inform the World Heritage Committee and the global community could include efforts to: f augment historical data collation efforts and expand monitoring of reef condition for all World Heritage properties containing coral reefs; f enhance analysis of past bleaching and heat stress events to test for impacts of back-to-back heat stress or local factors that alter reef resilience; f undertake high-resolution (downscaled) future projection analysis under both RCP2.6 and the new RCP1.9 scenarios, to fully understand the implications of meeting the long�term goal of the Paris Agreement for World Heritage properties. Under RCP2.6 emissions peak during the current decade, 2010-2020, and then decline substantially, resulting in a projected peak global temperature increase of 1.6°C and returning to 1.5°C or below by 2100g . RCP1.9 is being discussed as an emissions pathway that results in a peak global warming of around 1.5°C, and returning to around 1.3°C by 2100; f increase capacity for the detection of impacts on corals, prior to visible signs of bleaching, and how impacts may be alleviated by physical and other mechanisms that confer bleaching resistance and resilience; f expand the consideration of impacts beyond corals, to include broader ecosystem impacts of warming and acidification, and their socio-economic importance; f identify and protect coral reefs (World Heritage or other) that stand in the best position to survive climate change and which are best located to help regenerate other coral communities once ocean conditions have stabilized; and f develop guidance to support the management of World Heritage reefs in the face of climate change, and for industries that depend upon reefs (to enhance social adaptive capacity). | Adapt-MitigImpacts | 12 - 12 |
| UNESCO | Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | Efforts to build resilience by reducing local human pressure are central to World Heritage conservation, and are matters of concern to the World Heritage Committee, that provides requests and recommendations through the State of Conservation process of the 1972 World Heritage Convention. However, while essential, local management is no longer sufficient to protect the OUV of these properties. | Adapt-Mitig | 5 - 5 |
| UNESCO | Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | Reduced atmospheric CO2 pathways give corals time to adapt and provide two key opportunities, through: f improving opportunities for adaptation by corals, by reducing the rate of future warming, and extending the window before a critical threshold is reached; and f expanding opportunities for the research and development of new solutions, reducing interacting stressors, developing new models for management, new techniques for rehabilitation, and innovations in industry and manufacturing to reduce CO2 emissions and implement sequestration to remove CO2 from the atmosphere and upper ocean. | Adapt-Mitig | 11 - 11 |
| UNESCO | Impacts of Climate Change on World Heritage Coral Reefs - UNESCO 2017 | increases this century, and delays the year when a critical threshold is crossed. It also results in eventual stabilization of temperatures and heat stress after 2100. Changing from RCP8.5 to RCP4.5 provides an additional 12 years (on average) of capacity for adaptive responses to occur and reduces the proportion of sites experiencing severe stress levels in any given year. While clearly not enough to 'save' reefs and insufficient as a solution, this is an important opportunity, 'buying time' for natural adaptation, and the search for solutions. Even greater emissions reductions, such as under RCP2.6, and delivering on the Paris Agreement target of "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C"32 offers the only opportunity to prevent coral reef decline globally, and across all 29 reef-containing natural World Heritage sites. | Adapt-Mitig | 12 - 12 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | The group of experts prepared a report on "Predicting and Managing the Effects of climate change on World Heritage' (the Report), as well as a 'Strategy to Assist States Parties to the Convention to Implement Appropriate Management Responses" (the Strategy). The Committee reviewed and endorsed these two documents1 at its 30th session (Vilnius, 2006) (Decision 30 COM 7.1), and requested all States Parties to implement the strategy so as to protect the out�standing universal values, integrity and authenticity of the World Heritage properties from the adverse impacts of climate change. | Adapt-MitigImpacts | 4 - 4 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | 1 Background CC Policy Doc-eng 13/05/08 16:43 Page 2<br>3 Preamble and purpose According to the IPCC3, the average temperature of the earth's surface has risen by 0.74 degrees C° since the late 1800s4 and it is projected to increase by another 1.1 to 6.4 degrees C° by the year 2099. The sea level rose on average by 10 to 20 cm during the 20th century, and an additional increase of 0.18 to 0.59 cm is projected by the end of the current century5. Small Island Developing States (SIDS) are most vulnerable to such sea level rise and severity of extreme weather conditions and could, in some cases, even become uninhabitable6. With the 4th IPCC Assessment Report (Climate Change 2007) it has been widely acknowl�edged that the scientific basis for understanding the impacts of climate change and options for adaptation and mitigation have been clearly established. | Adapt-MitigImpacts | 4 - 5 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Deeply concerned about the adverse impacts which climate change is having or may have on the Outstanding Universal Value (OUV), integrity and authenticity of World Heritage properties, the World Heritage Committee launched an ini�tiative at its 29th session (Durban 2005) to investigate the issue in detail. The resulting report on 'Predicting and Managing the effects of Climate Change on World Heritage', as well as a 'Strategy to assist States Parties to Implement Appropriate Management Responses' were considered and endorsed by the Committee at its 30th ses�sion (Vilnius, 2006)10. These two documents present a detailed analysis of the threats posed to both natural and cultural World Heritage properties by climate change and discuss some of the preventive and corrective actions that 3. Intergovernmental Panel on Climate Change – 'IPCC 4th Assessment Report: Summary for Policymakers'. | Adapt-MitigImpacts | 5 - 5 |

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| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Mindful of the various issues already covered in detail in the above-mentioned report and strategy, this policy document is principally aimed at providing the World Heritage deci�sion / policy-makers with guidance on a limited number of key issues (synergies, research needs and legal issues). For all other general issues dealing with the impacts of climate change on World Heritage properties and management responses document WHC-06/30.COM/7.1 (World Heritage Paper No. 22) should be consulted. | Adapt-MitigImpacts | 6 - 6 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Adaptation: the adjustment in natural or human systems, in response to actual or expected climatic stimuli or their effects that moderate harm or exploit beneficial opportuni�ties (IPCC). | Adapt-MitigImpacts | 6 - 6 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | The World Heritage Centre and the Advisory Bodies will cooperate with States Parties and other relevant organiza�tions during the reactive monitoring and periodic reporting processes and in research activities, so that the impacts of, adaptation to, and mitigation of climate change are prop�erly assessed, reported and managed. The use of the UNFCCC Compendium on methods and tools to evaluate impacts of, vulnerability and adaptation to, climate change will be promoted. | Adapt-MitigImpacts | 6 - 6 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Some properties may be able to be involved in sequestra�tion and carbon offset activities as part of broader national mitigation approaches and this will be the pri�mary level of focus. They will also integrate these actions in risk preparedness policies and action plans, making use of the 'Strategy for Risk Reduction at World Heritage Properties'12. | Adapt-MitigImpacts | 7 - 7 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | States Parties and managers of individual World Heritage properties will include climate change messages in commu�nication, education and interpretation activities as appro�priate, to build public awareness and knowledge of climate change, its potential impacts on World Heritage properties and their values, and the ongoing activities or available options for adaptation and mitigation. | Adapt-MitigImpacts | 7 - 7 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Principles Research on climate change at World Heritage properties will be carried out through partnerships with and influence of those who are conducting or can carry out such research or who fund research programmes. The site-specific nature of the climate change problems facing properties, make them ideal as laboratories for long-term climate change impact monitoring and testing of innovative adaptation solutions. | Adapt-MitigImpacts | 7 - 7 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Research must draw wider conclusions or develop approaches (such as management frameworks) that enable knowledge transfer to take place among properties and regions. For example, the approach taken by the EU 6th Framework 12. Document WHC-07/31.COM/7.2 13. http://unfccc.int/files/essential_background/background_publications_htmlpdf/application/pdf/nwp_en_070523.pdf CC Policy Doc-eng 13/05/08 16:43 Page 5 6 Programme research project on Global Climate Change Impacts on the Built Heritage and Cultural Landscapes14 in producing a Climate Change Vulnerability Atlas and in developing drying strategies for different types of historic structures for the European Region can be a model for other regions of the world. | Adapt-MitigImpacts | 7 - 8 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Three different strands of research needs have been identified: 1. Research that responds to increased risk factors such as fire, drought, floods, avalanches, glacial lake outbursts, to support disaster management plans for properties. | Adapt-MitigImpacts | 8 - 8 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Advocacy and implementation Research in relation to the impacts of climate change on World Heritage properties will be linked to a clear course of follow-up action, including awareness raising. In particular the following will be ensured: 1. Research results will be translated into practical tools that can assist managers in developing their adaptive management responses. Options for the creation of a clearing-house mechanism of best-practice case studies on climate change, either separately or linked to similar mechanisms, such as those under the UNFCCC, CBD, UNCCD, or CMS will be investigated. | Adapt-MitigImpacts | 8 - 8 |

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| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Duties and obligations of States Parties under the Convention Article 4 is a central provision of the Convention: Each State Party to this Convention recognizes that the duty of ensuring the identification, protection, conserva�tion, presentation and transmission to future generations of the cultural and natural heritage referred to in Articles 1 and 2 and situated on its territory, belongs primarily to that State. It will do all it can to this end, to the utmost of its own resources and, where appropriate, with any international assistance and co-operation, in particular, financial, artistic, scientific and technical, which it may be able to obtain. (Emphasis added) 14. http://noahsark.isac.cnr.it/ CC Policy Doc-eng 13/05/08 16:43 Page 6<br>7 In the context of climate change, this provision will be the basis for States to ensure that they are doing all that they can to address the causes and impacts of climate change, in relation to the potential and identified effects of climate change (and other threats) on World Heritage properties situated on their territories. | Adapt-MitigImpacts | 8 - 9 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Article 6 of the World Heritage Convention Under Article 6, '…the States Parties to this Convention recognize that [such heritage] constitutes a world heritage for whose protection it is the duty of the international com�munity as a whole to co-operate'. Under Article 6 (3), States Parties undertake 'not to take any deliberate meas�ures which might damage directly or indirectly the cultural and natural heritage'. | Adapt-MitigImpacts | 9 - 9 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | • Para 132.4: State of conservation and factors affecting the property: when adverse effects resulting from climate change are evident, climate change will be included as a threat in the description of factors affecting the property, and it will be used as a baseline to monitor the state of conservation of the property in the future. | Adapt-MitigImpacts | 9 - 9 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Periodic reporting Under paragraph 199 of the Operational Guidelines, States Parties are requested to submit reports on legislative and administrative provisions adopted concerning the applica�tion of the Convention, including the state of conservation of their World Heritage properties. The World Heritage Committee will consider a specific obligation for States to report on the climate change related threats and impacts to OUV, and the efforts being made by way of mitigation and adaptation measures to address them. | Adapt-MitigImpacts | 10 - 10 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Management planning and management systems Sub-paragraph 5 of para 132 requires the inclusion of a management plan in the nomination submission process, and Para 118 contemplates the inclusion of risk prepared�ness as an element in World Heritage properties manage�ment plans and training strategies. The World Heritage Committee will consider strengthening the management planning and management system provisions of the Operational Guidelines concerning site level adaptation and mitigation measures. | Adapt-MitigImpacts | 10 - 10 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | The precautionary approach in World Heritage decision-making in the context of climate change Given the increasing application of the precautionary approach in international law and policy16, the World Heritage Committee will consider specifically incorporating reference to it within the Operational Guidelines. The fact that the approach has been adopted in the UNFCCC pro�vides a useful example, and its application to protection and conservation concerning World Heritage is obvious. The UNFCCC includes this under Article 3 (Principles) as follows: 'The Parties should take precautionary measures to antici�pate, prevent or minimize the causes of climate change and mitigate its adverse effects. Where there are threats of seri�ous or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such meas�ures, taking into account that policies and measures to deal with climate change should be cost-effective so as to ensure global benefits at the lowest possible cost. To achieve this, such policies and measures should take into account different socio-economic contexts, be comprehen�sive, cover all relevant sources, sinks and reservoirs of greenhouse gases and adaptation, and comprise all eco�nomic sectors. Efforts to address climate change may be carried out cooperatively by interested Parties.'17 The explicit adoption of the precautionary approach by the World Heritage Committee as a consideration in decision�making in general will encourage States Parties and the Advisory Bodies to use the emerging knowledge relating to the implementation of the precautionary approach18 to deal more actively with risk and uncertainty when making decisions concerning the effects of climate change on World Heritage properties. | Adapt-MitigImpacts | 10 - 10 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | iii. World Heritage properties will be used wherever appro�priate and possible as a means to raise awareness about the impacts of climate change upon World Heritage to act as a catalyst in the international debate and obtain support for policies to mitigate climate change, and to communicate best practices in vulnerability assess�ments, adaptation strategies, mitigation opportunities, and pilot projects. | Adapt-MitigImpacts | 11 - 11 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | 5. Research in relation to impacts on integrity (size, shape, boundaries, buffer zones, management, threats, etc.): • To identify key direct and indirect impacts of climate change on the integrity of specific properties and how this research can best be used to guide field manage�ment responses at the site level. | Adapt-MitigImpacts | 12 - 12 |

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| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | 2. Monitoring change: It is important to recognize that a large amount of data and tools are already available in complementary fields for cul�tural heritage, for example in geo-archaeology and in microbiology. This research needs to be built upon, though clearly specific research is needed because of the general lack of research in climate change impacts and cultural her�itage. There are also currently no standards, protocols, indi�cators and databases within the field of cultural heritage and climate change. This suggests that research needs to focus in two directions: on the impact of climate change on local scales, especially in cities, where there are concentra�tions of people and cultural heritage; and in the develop�ment of new technological tools – advanced yet simple to use on site, to enable monitoring of change and to validate conservation decisions. While sensors need to be both inex�pensive and sturdy, it is important that much progress is made in technology development, with a focus on remote sensing products such as gas phase bio-sensing. This will enable the small group of scientists working in this field to provide remote support to site managers who are prioritiz�ing the managed change of cultural heritage. | Adapt-MitigImpacts | 13 - 13 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | It is necessary to assign probabilities of damage to specific properties, but this requires ensembles of climate models to be used and for research to be carried out on sub-grid climate models. This approach would have a much better spatial resolution than the current 50km grid. State-of-the�art computer simulation must be used if site managers are to understand better the potentially catastrophic effect on properties of sporadic and extreme events and to use risk management to forecast the effect of natural disasters on specific World Heritage properties. Research on disaster preparedness must therefore focus on hazard recognition and the quantification and prioritization of climate change risks. | Adapt-MitigImpacts | 13 - 13 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Présentation de rapports périodiques Conformément au paragraphe 199 des Orientations, les États parties sont invités à présenter des rapports sur les dispositions législatives et les règlements administratifs qu'ils auront adoptés pour l'application de la Convention, incluant l'état de conservation des biens du patrimoine mondial situés sur leur territoire. Le Comité du patrimoine mondial envisagera l'obligation spécifique pour les États parties de signaler les dangers et les impacts pour la VUE liés à l'évolution du climat, et les efforts accomplis à travers des mesures d'adaptation et d'atténuation pour y faire face. | Adapt-MitigImpacts | 25 - 25 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | The composition and distribution of natural, human and cultural ecosystems are expected to change as species and populations respond to the new conditions created by cli�mate change. Species may be forced to shift their ranges, but this movement becomes difficult or impossible in heav�ily fragmented landscapes7. Climate change exacerbates the incidence of pests, pathogens and fires. Warmer tem�peratures in deserts could threaten species that now exist near their heat tolerance limit, and desertification will increase. The projected declines in glaciers, permafrost and snow cover will affect soil stability and hydrological sys�tems, eventually causing many river systems to dry up. In coastal and marine ecosystems, increased coral bleaching and mortality would profoundly affect the productivity of reef ecosystems8. Thus, climate change will adversely affect, and indeed is already affecting the conservation of World Heritage natural properties9 and the ecological sys�tems that sustain life. | Adapt-Mitig | 5 - 5 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | The World Heritage Convention's comparative advantage lies in its management of outstanding cultural and natural heritage properties around the world, and the breadth of States Parties' obligations to protect these properties. | Adapt-Mitig | 6 - 6 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Actions taken at these iconic properties attract consider�able attention and can influence the adoption of good management practices elsewhere. Therefore, the World Heritage Centre will focus its efforts on optimizing this comparative advantage by actively promoting, in coopera�tion with States Parties, the use of World Heritage proper�ties in the activities of other conventions, international bodies and programmes working on climate change. | Adapt-Mitig | 6 - 6 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Recognizing the overarching objective of safeguarding the outstanding universal values of World Heritage properties, World Heritage properties can serve as laboratories where monitoring, mitigation and adaptation processes can be applied, tested and improved. They can partner with rele�vant organizations in field activities on mitigation and adaptation strategies, methodologies, tools and/or pilot projects. The World Heritage Centre and the Advisory Bodies will lead and coordinate in the collection and wide dissemination of lessons learned and best practice devel�oped through such partnerships. | Adapt-Mitig | 6 - 6 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | States Parties and managers of individual World Heritage properties will consider undertaking site-level monitoring, mitigation and adaptation measures, where appropriate. | Adapt-Mitig | 7 - 7 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | States Parties may use the opportunities presented by the 'Nairobi Work Programme on Impacts, Vulnerability, and Adaptation to Climate Change'13 under the UNFCCC, and other ongoing processes, to address adaptation to climate change at World Heritage properties. They are encouraged to participate in the United Nations Climate Change confer�ences with a view to achieving a comprehensive post-Kyoto agreement. | Adapt-Mitig | 7 - 7 |

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| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | States Parties work at the national level, but will also estab�lish appropriate thematic, regional and global linkages and cooperation to understand, access, fund and implement mitigation and adaptation strategies, actions, tools and/or pilot projects. Efforts at World Heritage property level to mitigate and adapt to climate change will be coordinated with other conventions and international bodies working on climate change, to create synergies, integrate activities and avoid duplication. | Adapt-Mitig | 7 - 7 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | These provide the foundation for capacity building for adaptive management among site managers and will receive high priority. In addition, specific research priorities for natural and cultural properties are detailed in the Annex 1 and States Parties will work with appropriate part�ners to support and fund these research needs. | Adapt-Mitig | 8 - 8 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | In addition to the duty set out in Article 4, Article 5 places a number of obligations on States Parties: To ensure that effective and active measures are taken for the protection, conservation and presentation of the cul�tural and natural heritage situated on its territory, each State Party to this Convention shall endeavour, in so far as possible, and as appropriate for each country (…) To take the appropriate legal, scientific, technical, admin�istrative and financial measures necessary for the identi�fication, protection, conservation, presentation and rehabilitation of this heritage. | Adapt-Mitig | 9 - 9 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | • Para 132.5: Protection and management: relevant provi�sions will be considered to incorporate climate change concerns in the planning and management requirements to ensure adequacy of adaptation and mitigation meas�ures at the site level. | Adapt-Mitig | 9 - 9 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | These criteria will be used not only while considering the inclusion of properties on the List of World Heritage in Danger, but will also form the basis for prioritising vulnera�bility assessment, mitigation and adaptation activities. The need for incorporating these criteria into the Operational Guidelines will be considered only after assessing their utility for this purpose. | Adapt-Mitig | 10 - 10 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | CC Policy Doc-eng 13/05/08 16:43 Page 8<br>9 Mitigation of emissions by the World Heritage community While the main focus of the response strategy under the World Heritage Convention will be on site-level adaptation, several activities under the Convention and by the World Heritage community result in the emission of greenhouse gases. Therefore, mitigation options will be explored and actions taken for reducing and/or offsetting these emis�sions (e.g. as done in the case of Yosemite National Park, California, USA), and these practices will be publicized. The network of World Heritage cities offers an unparalleled opportunity to promote and highlight the use of energy efficient and carbon neutral technologies. | Adapt-Mitig | 10 - 11 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | Mitigation measures will also include the following: a recycling program at the World Heritage Centre with pro�gressive, phased targets; progressively increasing use of web- and video-conferencing technologies in order to obvi�ate the need to undertake travel; progressively decreasing paper usage at Committee meetings by encouraging the dissemination and utilization of electronic documents; pro�gressively decreasing the number of air trips on Committee business; measures to ensure that meetings will be carbon�neutral (e.g. Christchurch, 2007); and where airline flights are necessary and unavoidable, the purchasing of carbon offsets from a Gold Standard, including providing meeting budgets with financing for such offsets. | Adapt-Mitig | 11 - 11 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | • To identify the climate sensitivity of species and ecosys�tems to provide a greater indication of those values which are most susceptible to climate change (such as from fire, invasive species, drought, etc) and also to identify how much climate change (direction, magni�tude, rate, means vs. extremes) is too much in relation to specific values. Understanding the climatic thresh�olds of key species and communities is essential for planning effective management responses. | Adapt-Mitig | 12 - 12 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | 6. Other research in relation to natural World Heritage properties: • To identify how properties contribute to greenhouse gas emissions, sequestration and storage. This could assist in recognizing carbon values of forest and other properties to increase leverage for conservation and potential for sustainable financing through carbon offset projects. | Adapt-Mitig | 12 - 12 |
| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | 3. Should the Convention, and its associated Operational Guidelines, seriously consider the fact that for some natural properties it will be impossible to maintain the 'original' OUV for which they were originally inscribed on the World Heritage List, even if effective adaptation and mitigation strategies are applied, therefore requiring an 'evolving' assessment of OUV? | Adapt-Mitig | 14 - 14 |

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| UNESCO | Policy Document on the Impacts of Climate Change on World Heritage Properties - UNESCO 2008 | L'évolution du climat amplifie l'incidence des parasites, des vecteurs pathogènes et des incendies. Le réchauffement de la température dans les déserts pourrait menacer des espè- ces qui ont quasiment atteint aujourd'hui leur seuil de tolé- rance à la chaleur, et la désertification va s'étendre. Le recul projeté des glaciers, du pergélisol et de la couverture neigeuse affectera la stabilité des sols et les régimes hydro�logiques, ce qui finira par provoquer l'assèchement de nombreux cours d'eau. Dans les écosystèmes côtiers et marins, une augmentation du blanchissement et de la mortalité des coraux affecterait profondément la producti�vité des écosystèmes coralliens8. Ainsi, le changement climatique affectera-t-il, si ce n'est déjà fait, la conservation des biens naturels du patrimoine mondial9 et des systèmes écologiques qui soutiennent la vie. | Adapt-Mitig | 20 - 20 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | As this report shows, World Heritage properties provide opportunities for both climate mitigation and adaptation. For example, well-preserved forests and coastal habitats can help store carbon and provide vital ecosystem services, including natural protection against storms and floods. World Heritage sites can also act as learning laboratories for the study and mitigation of climate impacts, as well as being places to test resilient management strategies. | Adapt-MitigImpacts | 7 - 7 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Climate change is both a direct threat and a threat multiplier. Worsening climate impacts are cumulative, and often exacerbate the vulnerability of World Heritage sites to many other existing risks, including uncontrolled tourism, lack of resources for effective management, war, terrorism, poverty, urbanization, infrastructure, oil and gas 12 World Heritage and Tourism in a Changing Climate Box 1 The World Heritage Convention and criteria for selection Adopted in 1972, the World Heritage Convention protects natural diversity and cultural wealth of global significance, the importance of which transcends national boundaries (UNESCO). The roots of the convention lie in efforts during the late 1950s and 1960s to encourage international cooperation to protect cultural heritage and extraordinary natural areas for the benefit of future generations, and for all humankind. | Adapt-MitigImpacts | 14 - 14 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Although there is potential for some species to move and shift their ranges in response to climate change in natural World Heritage sites, and many ecosystems exhibit some degree of climate resilience, adaptive capacity is reduced by other stresses including habitat loss, degradation and fragmentation. The speed of climate change and lack of habitat connectivity will severely limit ecosystem response in many cases, and will require the adoption of new and innovative management practices (Welling et al. 2015; Stein et al. 2014; Markham 1996). | Adapt-MitigImpacts | 15 - 15 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Protecting large intact ecosystems is the most effective way of maintaining the adaptive capacity of natural World Heritage sites. For existing sites this means an increased emphasis on expanding and managing buffer zones and on ensuring connectivity between sites and other protected areas (Kormos et al. 2015). The need to adapt boundaries may be a significant issue for World Heritage sites in a changing climate, and in many technology, monumental arts, town�planning or landscape design; (iii) To bear a unique or at least exceptional testimony to a cultural tradition or to a civilization which is living or which has disappeared; (iv) To be an outstanding example of a type of building, architectural or technological ensemble or landscape which illustrates (a) significant stage(s) in human history; (v) To be an outstanding example of a traditional human settlement, land-use, or sea-use which is representative of a culture (or cultures), or human interaction with the environment especially when it has become vulnerable under the impact of irreversible change; (vi) To be directly or tangibly associated with events or living traditions, with ideas, or with beliefs, with artistic and literary works of outstanding universal significance (the Committee considers that this criterion should preferably be used in conjunction with other criteria); (vii) To contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance; (viii) To be outstanding examples representing major stages of Earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features; (ix) To be outstanding examples representing significant on-going ecological and biological processes in the evolution and development of terrestrial, freshwater, coastal and marine ecosystems and communities of plants and animals; (x) To contain the most important and significant natural habitats for in-situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation. | Adapt-MitigImpacts | 15 - 15 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Climate change and the World Heritage Convention It has now been more than a decade since the issue of climate change impacts on natural and cultural heritage properties was formally brought to the attention of the World Heritage Committee (Welling et al. 2015). At its 29th session in Durban, South Africa in 2005, the World Heritage Committee called on States Parties to identify the properties most at risk from climate change and encouraged UNESCO "to ensure that the results about climate change affecting World Heritage properties reach the public at large, in order to mobilize political support for activities against climate change and to safeguard in this way the livelihood of the poorest people of our planet (Decision 29 COM 7B.a). This resulted in a ground-breaking report, Predicting and Managing the Effects of Climate Change on World Heritage (UNESCO 2007b), as well as the Strategy to Assist States Parties to the Convention to Implement Appropriate Management Responses (UNESCO 2007c). At its 30th session (Vilnius, 2006), the World Heritage Committee requested all States Parties to implement the strategy so as to protect the OUV, integrity and authenticity of World Heritage properties from the adverse impacts of climate change. In 2007, at its 16th session, the General Assembly of States Parties adopted a binding Policy Document on the Impacts of Climate Change on World Heritage Properties (UNESCO 2007a). Progress on implementing the strategy and the policy in most countries, however, has been quite limited to date. Furthermore, there has not yet been a comprehensive, science-based assessment of climate impacts and vulnerability at all World Heritage sites. Nonetheless, an increasing amount of data about climate change in relation to World Heritage sites has become available during the last decade or so. | Adapt-MitigImpacts | 16 - 16 |

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| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | 14 World Heritage and Tourism in a Changing Climate WH_and_Tourism_23_may.indd 14 H_and_Tourism_23_may.indd 14 24/05/2016 05:25 4/05/2016 05:25 Also in 2014, the International Union for the Conservation of Nature's IUCN World Heritage Outlook declared climate change to be the most serious potential threat to natural World Heritage sites worldwide (Osipova et al. 2014a). Looking more widely at all types of threat, the report also noted that only half of all natural or mixed sites were routinely monitored; more than a third had serious concerns about the levels of conservation; and 13 per cent of sites had ineffective levels of protection and management. Monitoring threats and impacts of all types, including climate change, is critical for ensuring that sites retain their OUV status. In many countries, IUCN found that existing monitoring programmes and management were weak or insufficient (Osipova et al. 2014a). | Adapt-MitigImpacts | 16 - 17 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Official reporting on threats to specific sites under the World Heritage Convention is through state of conservation (SOC) reports produced by the UNESCO World Heritage Centre and the advisory bodies – the International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM), the International Council on Monuments and Sites (ICOMOS) and IUCN. The publicly accessible online World Heritage State of Conservation Information System contains many reports that identify climate-related threats (http://whc.unesco.org/en/soc). During the period 1979–2013, more than 2 600 SOC reports were submitted, with 70 per cent of natural and mixed sites and 41 per cent of cultural sites being assessed at least once. Some 77 per cent of all reports identified management and institutional factors as threats, including a lack of management plans or problems with implementing them; boundary issues; problems with legal frameworks and governance; and scarcity of financial or human resources. The second most reported category of threat was from buildings and development including housing, commercial and industrial India's Elephanta Caves are one of 130 cultural World Heritage sites identified in a recent academic study as being at long-term risk from sea-level rise. | Adapt-MitigImpacts | 17 - 17 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Three ground-breaking aspects of the Paris Agreement will be vital for the future management and preservation of World Heritage sites. First, the new emphasis on preventing deforestation will increase the importance of forest conservation efforts in World Heritage sites, their buffer zones and surrounding areas. Eighteen Latin American governments at COP21 pledged to use their protected area systems as tools for climate mitigation and adaptation. Key measures include carbon sequestration and preserving ecosystem services to reduce disaster risk, thus highlighting the positive role that natural World Heritage sites can play in national climate strategies. A recent IUCN study found that an estimated 5.7 billion tonnes of forest biomass carbon is stored within natural World Heritage sites in the pan-tropical regions of the world alone (Osipova et al. | Adapt-MitigImpacts | 19 - 19 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Secondly, the Paris Agreement highlighted the need to implement a new international approach to managing climate-driven disasters by shifting from a focus on reducing disaster losses to a comprehensive management vision – building on the Sendai Framework for Disaster Risk Reduction 2015–2030 (UNISDR 2015) – that includes risk assessment, adaptation planning and resilience building. | Adapt-MitigImpacts | 19 - 19 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Goal 13 calls for taking "urgent action to combat climate change and its impacts". Goal 14's targets focus on sustainable use and conservation of the oceans, including minimizing and addressing the impacts of ocean acidification; conserving at World Heritage and tourism in a changing climate 17– WH_and_Tourism_23_may.indd 17 H_and_Tourism_23_may.indd 17 24/05/2016 05:25 4/05/2016 05:25 18 World Heritage and Tourism in a Changing Climate least 10 per cent of coastal and marine areas; and increasing the economic benefits to small island developing states through the sustainable use of marine resources, including through tourism. | Adapt-MitigImpacts | 19 - 20 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Responsible tourism can be a driver of sustainable development and the preservation of natural and cultural heritage, but if unplanned and poorly managed it can be socially, economically and culturally disruptive and cause damage and degradation to sensitive ecosystems, landscapes, monuments and communities (WHC 2012). The 2011 ICOMOS Paris Declaration on Heritage as a Driver of Development (ICOMOS 2011) stated clearly that "local participation, drawing on local perspectives, priorities and knowledge, is a pre�condition of sustainable tourism development". | Adapt-MitigImpacts | 20 - 20 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Despite the growing body of academic research demonstrating the risks posed to tourism by climate change, concern remains low among tourism operators, with many wrongly believing that there is too much uncertainty around climate impacts to justify action and that adaptation will be relatively easy (Nichols 2014). In fact, adaptation options at many destinations are quite limited and there is an urgent need for the industry to address the issue more seriously. A 2008 report from the UNWTO and UNEP noted that the policy changes and investments needed for effective adaptation may take decades to put in place. The report called on the tourism sector to urgently begin developing and implementing response strategies, especially for destinations most likely to be affected by climate change by mid-century (UNWTO 2008). A recent academic assessment of the implications of the latest climate science for the tourism sector concluded that "the political and business case for a sectoral response on climate change has never been stronger" and "tourism absolutely cannot afford not to ... dedicate increased efforts to understand the implications of climate change" (Scott et al. 2016). | Adapt-MitigImpacts | 21 - 21 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | However, there are often negative impacts associated with uncontrolled or unplanned tourism development, including a lack of visitor access management, cultural disruption and poorly planned infrastructure such as airports, cruise ship terminals and hotels. Such developments can contribute to local environmental problems including excessive water consumption, water pollution, waste generation, habitat damage and threats to local cultures and traditions (UNEP and UNWTO 2012). | Adapt-MitigImpacts | 23 - 23 |

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| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | In summary, several general conclusions regarding the interaction of climate change and tourism at World Heritage sites can be drawn from an analysis of the case studies: • climate change can have a major negative effect on the attractions and assets that draw tourists to World Heritage destinations and thereby reduce the potential for economic and sustainable tourism development; • over the long term the OUV, integrity and authenticity of some World Heritage sites could eventually be degraded by climate change to the extent that some properties may have to be added to the List of World Heritage in Danger and consideration eventually given to their de-listing; • at World Heritage sites where tourism infrastructure developments and uncontrolled or poorly managed visitor access are already a problem, climate change impacts – for example, extreme weather events, coastal flooding and erosion – are likely to exacerbate problems and increase site vulnerability; • climate change impacts have the potential to increase visitor safety concerns for the tourism industry, especially at sites where increased intensity of extreme weather events or vulnerability to floods and landslides are projected; • national and regional tourism and development strategies and site visitor management plans, with very few exceptions, currently fail to take climate change impacts into account; • climate change is too often regarded as a long�term potential problem for World Heritage sites rather than as an imminent or near-term issue, so assessment of climate vulnerability tends to be under-represented in state of conservation reports; • site managers often lack the financial resources and expertise or training necessary to undertake comprehensive climate vulnerability assessments and the development and implementation of adaptation and resilience strategies. | Adapt-MitigImpacts | 28 - 28 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | WH_and_Tourism_23_may.indd 26 H_and_Tourism_23_may.indd 26 24/05/2016 05:25 4/05/2016 05:25<br>Recommendations 27– T he situation analysis in this report, along with the case studies and site sketches, demonstrates the urgent need to understand, monitor and respond better to climate change threats to World Heritage sites, as well as the interactions between climate change and the tourism sector. The requirements of the binding Policy Document on the Impacts of Climate Change on World Heritage Properties that was adopted by the General Assembly of States Parties to the World Heritage Convention at its 16th session (Paris, 2007), as well as the 2006 Strategy to Assist States Parties to the Convention to Implement Appropriate Management Responses, should be fully implemented. Additional action should be taken to increase the resilience of cultural and natural heritage and reduce the impacts of both climate change and tourism. These recommendations are intended for the international community, States Parties, government policy makers, the tourism industry and site management authorities. | Adapt-MitigImpacts | 28 - 29 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | States Parties are asked to consider site-level monitoring, mitigation and adaptation measures and establish thematic, global and regional links to understand, access, fund and implement mitigation and adaptation strategies. These efforts should be coordinated with other conventions and international bodies. States Parties should work to build public awareness and knowledge of climate change and its potential impacts on World Heritage properties and their values. The policy also calls for more research and research funding partnerships to better understand the consequences and costs of climate change for World Heritage sites as well as for societies, particularly traditional ones, or in sites such as cultural landscapes where the way of life contributes to their outstanding universal value (OUV). Consideration should be given to updating the World Heritage Committee's Strategy to Assist States Parties to the Convention to Implement Appropriate Management Responses in the light of the most up-to-date knowledge on site vulnerability and management options, potential resilience strategies and the latest climate science. Research, including on climate change, should continue to inform the implementation of the convention and management responses. | Adapt-MitigImpacts | 29 - 29 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | This review should take account of the interaction of climate change with existing stressors such as tourism pressures, illegal harvesting of natural resources, oil and gas developments, armed conflict and poverty. Systems for monitoring and early warning of climate change impacts should be developed and implemented. UNESCO, working with other international organizations including the United Nations Environment Programme (UNEP), United Nations Development Programme (UNDP), International Labour Organization Recommendations WH_and_Tourism_23_may.indd 27 H_and_Tourism_23_may.indd 27 24/05/2016 05:25 4/05/2016 05:25<br>28 World Heritage and Tourism in a Changing Climate (ILO), United Nations Industrial Development Organization (UNIDO) and the World Tourism Organization (UNWTO), should prioritize the mapping of impacts using World Heritage properties to field test management strategies and approaches in order to improve resilience and minimize impacts from climate change. | Adapt-MitigImpacts | 29 - 30 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Analyse archaeological data and cultural heritage to use what can be learned from past human responses to climatic change to increase climate resilience for the future Some of the archaeological resources that can provide insights for our future by opening windows on the past are in danger of being lost, particularly in rapidly warming Arctic regions and along eroding coastal and riverine sites. An international response is needed to identify the sites most at risk and to synthesize and use lessons gleaned from the archaeological record and cultural heritage that can help with the development of adaptation strategies for natural and cultural heritage (IHOPE 2015; Jarvis 2014; Rockman 2012). | Adapt-MitigImpacts | 31 - 31 |

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| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | GOVERNMENT POLICY MAKERS AND THE TOURISM INDUSTRY Develop strategies and polices that lead to greenhouse gas emission reductions from the tourism sector that are in line with the goals of the Paris Agreement Carbon emissions from transportation and accommodation in the tourism sector are predicted to triple by 2035 and the paucity of technological mitigation options, especially for the rapidly growing long-haul travel sub-sector, means that emissions related to tourism are likely to continue to grow (Fischedick et al. 2014) unless sector-wide action is taken. The response from the industry needs to be on a scale that can match the seriousness and urgency of the problem (OECD 2011). The sector, including the travel and aviation industries, large international tour operators, small businesses, resorts and destinations, must address the issue of its emissions growth. Operators should audit, monitor and reduce their carbon emissions and minimize other environmental impacts. Sector-wide strategies and policies will require the development and adoption of less energy-intensive transportation and accommodation operations and the promotion of sustainable tourism. | Adapt-MitigImpacts | 31 - 31 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Create detailed climate change action strategies for tourism management and development at vulnerable sites Multi-stakeholder climate change strategies for tourism should be developed for sites where climate change has been identified as a current or future threat to their OUV, or where climate and tourism impacts together are increasing the vulnerability of the site and local communities. States Parties should work together with site management authorities, local communities, research institutions and the tourism industry to create strategies that: • raise awareness of the OUV of natural and cultural sites and their importance as key assets for the tourism sector; • provide a framework for the tourism industry to respond to climate change, including reducing their own carbon emissions; • engage tourism operators in action that contributes to stewardship in the context of a changing climate; • help to leverage resources in support of climate preparedness and resilience; • provide a coordinating mechanism for government and the tourism industry to address policy and management issues to ensure an adequate response to climate change. | Adapt-MitigImpacts | 31 - 31 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | WH_and_Tourism_23_may.indd 29 H_and_Tourism_23_may.indd 29 24/05/2016 05:25 4/05/2016 05:25<br>30 World Heritage and Tourism in a Changing Climate Fully integrate climate change impacts and preparedness into national and site-level tourism planning, policies and strategies The importance to tourism of preserving World Heritage sites in a changing climate must be emphasized, recognized and understood by all involved in tourism planning at the national level, and in the public and private sectors. The management of World Heritage properties for tourism needs to take climate change vulnerability and protection into account. The potential impacts of climate change on the value and integrity of World Heritage sites, as well as the interactions between climate and tourism that could exacerbate negative effects, should be fully considered and integrated into national, regional and local tourism strategies and management. The current lack of integrated cross-sectoral assessments that analyse the full range of potential impacts and their interactions needs to be addressed urgently (Scott et al. 2016). | Adapt-MitigImpacts | 31 - 32 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Site management plans should closely reflect the predicted operational risks and potential impacts of both climate change and tourism. | Adapt-MitigImpacts | 32 - 32 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Develop management tools for collecting data on tourism and climate impacts It is important to develop tools for evaluating the role of heritage and its enhancement in the context of tourism planning and development; to assess the socio-economic cost of the degradation of heritage values and heritage assets resulting from tourism and climate impacts; to help define and test best practices to ensure the long-term preservation of the cultural and economic resource; and to facilitate combined tourism development and climate impact assessment. | Adapt-MitigImpacts | 32 - 32 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Implement polices and action on climate change and tourism that are gender-responsive and participatory Women should have an equal voice in decision making on climate change responses as well as equal access to resources (Perry and Falzon 2014) and economic opportunities in the context of World Heritage management and sustainable tourism. Achieving gender equality and women’s empowerment in tourism will increase community resilience to climate impacts (UNESCO 2014). The public and private sectors must take proactive steps to mainstream gender in tourism policy, planning and operations; protect women’s rights; and facilitate women’s education, leadership and entrepreneurship in tourism (UNWTO 2011). In the preparation of nominations for World Heritage listing, site managers, local communities, national agencies and other stakeholders should document and analyse the experience of women and men in relation to the sites and work together to identify and understand appropriate issues related to gender equality. | Adapt-MitigImpacts | 32 - 32 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | SITE MANAGEMENT AUTHORITIES, INDIGENOUS PEOPLES AND LOCAL COMMUNITIES Fully incorporate the latest climate science and innovation in adaptation strategies into World Heritage site management planning World Heritage site management plans should also incorporate climate research in decisions on planning and implementation relating to the sustainability of sites and their OUV. Tourism management and development strategies should be science-based and make use of the latest data on climate change impacts, vulnerability and resilience. There is also an urgent need to incorporate and better understand the climate exposure and sensitivity of OUV in all World Heritage sites and to incorporate arrangements for climate change adaptation and resilience into management strategies, especially at the most vulnerable sites. UNESCO has developed a methodology to guide development of climate change adaptation strategies and plans at World Heritage sites (Perry and Falzon 2014). Experience gained and lessons learned in implementing these guidelines at site level, as well as from innovative strategies for adaptation and resilience-building being developed by States Parties, will be invaluable. | Adapt-MitigImpacts | 33 - 33 |

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| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Properties should have effective risk-reduction and disaster-response plans with action priorities in place, and update them regularly based on the latest climate change science. UNESCO's resource manual on managing disaster risks provides valuable guidance for managers and management authorities of cultural and natural World Heritage properties to help reduce the risks to these properties from natural and human-induced disasters (UNESCO 2010). Over the long term, management authorities should shift from planning primarily for disaster response and recovery, to strategies that focus on Recommendations 31– Over at least 2 000 years, the Ifugao people of the Philippines have created a productive landscape of exceptional beauty, but the Rice Terraces of the Philippine Cordilleras are now threatened by climate impacts and cultural change. | Adapt-MitigImpacts | 33 - 33 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | For site risk assessment, it is important to evaluate the widest possible range of impacts, including low�probability outcomes with large consequences (IPCC 2014). Site conservation and management strategies should recognize the inherent potential of sites to reduce disaster risk and adapt to climate change through ecosystem services (Osipova et al. 2014; Renaud and Sudmeier-Rieux 2013; Temmerman et al. 2013). Many World Heritage sites include habitat and ecosystems that serve as natural buffers against climate impacts and other disasters, or play a major role in climate mitigation as carbon stocks and sinks. | Adapt-MitigImpacts | 34 - 34 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Around the world, cultural traditions and indigenous knowledge are being lost. These traditions, vitally important in themselves and also often a significant part of the tourism experience, can be damaged, degraded or lost as a result of both tourist contact and climate impacts. It is crucial to arrest this decline and ensure that adaptation and resilience efforts aimed at preserving World Heritage fully incorporate local voices and maximize the use of local and traditional knowledge. UNESCO, through its Local and Indigenous Knowledge Systems (LINKS) programme, has already gained valuable experience in this field that could be leveraged to benefit the management of World Heritage sites. | Adapt-MitigImpacts | 34 - 34 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Establish targeted programmes to raise awareness among tourists, guides, site managers and local communities about the values and protection needs of World Heritage in a changing climate Tourists visiting World Heritage sites represent an important target audience for awareness raising about climate impacts, adaptation and mitigation. | Adapt-MitigImpacts | 34 - 34 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | High-quality interpretive materials and programmes can enhance awareness of the risks posed to cultural heritage, wildlife and natural ecosystems from climate change as well as adaptation strategies. Learning about climate change in the locale where its effects are being felt can be a powerful catalyst. Training for tour operators, guides and park rangers can have a magnifying effect. UNESCO's 2009 Strategy for Action on Climate Change identified enhancing public education and awareness about climate change, including encouraging the adoption of sustainable behaviours as a key strategic priority (UNESCO 2009). Innovative programmes involving visitor education and ranger training that could serve as models are being developed by the National Park Service in the USA (USNPS Online). | Adapt-MitigImpacts | 34 - 34 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | WH_and_Tourism_23_may.indd 35 H_and_Tourism_23_may.indd 35 24/05/2016 05:25 4/05/2016 05:25<br>36 World Heritage and Tourism in a Changing Climate In addition to human-caused deforestation, habitat loss and degradation, there is a risk that climate change, together with the expansion of tourism, will increase the probability of disease passing from humans to gorillas. Mountain gorillas are closely related to humans and therefore particularly vulnerable to human diseases. So, whilst tourism has brought many benefits for gorilla conservation and local communities, the proximity of gorilla families that are habituated to tourists increases their risk of exposure to diseases, some of which may be new to them. In Bwindi, habituated gorilla groups have been shown to have a higher incidence of parasites and bacterial infections than non-habituated groups (Kalema-Zikusoka et al. 2005). Even without tourism, however, the habitat overlap between gorillas and people around Bwindi, where there is a dense matrix of agriculture and settlements, has already increased the likelihood of gorillas being infected. | Adapt-MitigImpacts | 37 - 38 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | (WTTC 2015; UNESCOa) WH_and_Tourism_23_may.indd 36 H_and_Tourism_23_may.indd 36 24/05/2016 05:25 4/05/2016 05:25<br>Africa 37– and this particularly small gorilla group was more susceptible to infection because of stress from being tracked and viewed by tourist groups (Kalema-Zikusoka et al. 2002). If climate change causes increases in poor health amongst human populations around the park, which, for example, has been suggested as likely for a marginalized and poor local Batwa community (Berang-Ford et al. 2012), this could increase the risk of human-to�gorilla transmission of infections. Pioneering efforts, such as those of the NGO Conservation Through Public Health, to increase community heath and awareness in local villages and track gorilla health in order to reduce the risk of disease transmission and outbreaks are important, and several have been successfully under way for a number of years. | Adapt-MitigImpacts | 38 - 39 |

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| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | The importance of refugia  Climate change is projected to reduce the Cedrus   libani populations to only three refugial zones   by 2100, due to higher temperatures and water   stress from decreased moisture availability in the   Mediterranean region (Hajar et al. 2010a). While   plant communities can adapt to climate change by WH_and_Tourism_23_may.indd 43 H_and_Tourism_23_may.indd 43 24/05/2016 05:26 4/05/2016 05:26 44 World Heritage and Tourism in a Changing Climate  migrating to higher altitudes through seed dispersal   and gradual replacement, most of the cedar   forests of Lebanon are already isolated on or near   mountain summits, with nowhere further upslope   to go. The Arz el-Rab stand in the Qadisha valley is   an exception, being one of the three cedar forests   where there is higher-altitude habitat available for   potential migration, which makes their protection   all the more urgent (Hajar et al. 2010a). The cedars   of Ouadi Qadisha exemplify the vulnerabilities and   loss of resilience that plant communities face with   habitat degradation and fragmentation. | Adapt-MitigImpacts | 45 - 46 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | (UNESCOe; World Bank; IRD 2016, 2011; NOAA   2015; Gattuso 2014; Pew Charitable Trusts 2015)  WH_and_Tourism_23_may.indd 49 H_and_Tourism_23_may.indd 49 24/05/2016 05:26 4/05/2016 05:26 50 World Heritage and Tourism in a Changing Climate  Rice Terraces of the Philippine Cordilleras,   Philippines, 1995 (iii), (iv), (v)  The indigenous Ifugao people of the   Philippine Cordilleras have built and   developed their rice terraces over a period   of at least 2 000 years. This exceptionally   beautiful and important cultural landscape,   which draws tourists from all over the world,   is highly sensitive to climate change and is   already suffering negative effects. Warming   temperatures and increases in extreme rainfall   events are major problems. More intense   rainstorms will increase the instability of   the rice terraces built on steep mountain slopes, and cause landslides and erosion. An   additional problem is that local rice varieties   developed over hundreds of years under   stable climatic conditions by the Ifugao are   less adaptable to rapid climate change than   modern rice strains. Climate change comes   on top of cultural perturbations that include   the abandonment of rural tradition by young   people who are increasingly moving to   urban areas. (Manila Observatory; UNESCO f;   Katutubo 2015)  East Rennell, Solomon Islands, 1998 (ix)  Covered in dense tropical forest, Rennell Island   is the southernmost of the Solomon Islands   in the Western Pacific, and the largest raised   coral atoll in the world. The East Rennell World   Heritage site comprises 37 000 hectares at the   south of the island. The protected area includes   the brackish Lake Tegano, the largest lake on   any Pacific island. About 1 200 people live in   four villages within the property's boundaries   and East Rennell was the first World Heritage   site to be inscribed with responsibility for its   management lying with the traditional and   customary owners. East Rennell's outstanding   value lies in its undisturbed ecosystems and   ecological processes, which make it a natural   laboratory for the study of evolution and island   biogeography. The integrity of the site as well   as its nascent low-impact ecotourism potential   are now under threat from commercial   logging, the introduction of alien species   including the black rat (Rattus rattus), and   climate change. Warming-induced sea-level   WH_and_Tourism_23_may.indd 50 H_and_Tourism_23_may.indd 50 24/05/2016 05:26 4/05/2016 05:26 Asia and the Paciff c 51–  rise is directly affecting Lake Tegano, raising its   water levels and salinity. As a result, coconut   and taro crops, vital food staples for the local   communities, have been significantly reduced,   and houses, tourist lodges and the school have   been flooded. (UNESCO g)  Golden Mountains of Altai, Russian   Federation, 1998 (ix)  Although the Altai Mountains of Russia were   originally listed as a World Heritage site for its   biodiversity values, the region is equally important   for its incredible cultural and archaeological treasures. | Adapt-MitigImpacts | 51 - 53 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Coro was put on the List of World Heritage in   Danger in 2005 as a result of significant damage   caused by unusually intense rain and storms   in 2004 and 2005. The Central America and   Caribbean region has been identified as one of   the tropical parts of the world most responsive   to climate change, and has experienced a   marked increase in extreme weather events   including droughts, storms and floods over the   last 30 years. Increased intensity of periodic   rainstorms presents the primary threat to   the historic buildings of Coro and La Vela,   causing roof leaks, erosion of mud-roof mortar,   structural cracking, damp walls, wall collapses and landslides. Major strides in addressing   these problems have recently been made   through collaborative efforts involving the   state, community and traditional artisans. There   are positive signs that proactive adaptation   strategies can help maintain this important   heritage and tourism resource under changing   climate conditions. (UNESCOa)  WH_and_Tourism_23_may.indd 63 H_and_Tourism_23_may.indd 63 24/05/2016 05:26 4/05/2016 05:26 Athousand kilometres off the coast of   Ecuador, at the confluence of three Pacific   currents, lie the Galápagos Islands, an   archipelago of 18 large islands, three smaller   ones and more than 100 islets and rocks that   are home to a remarkable diversity of species   (UNESCOb). | Adapt-MitigImpacts | 65 - 66 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Climate change, particularly in the form of   sea-level rise and extreme weather, has more   recently become a threat, with changing   environmental conditions, landslides and floods   following torrential rains, and droughts leading   to habitat degradation and loss. Landslides   have also caused loss of life in the encroaching urban dwellings all around the forest. Tourism,   especially eco-tourism, has brought financial   resources and awareness for conservation, and   several non-governmental organizations have   been working on conservation and adaptation   initiatives, including restoration of degraded   forests and other habitats to reduce the impacts   of various threats. Improved connectivity   between forest fragments will be a vital   adaptive strategy as the climate continues to   change. (GIZ; TNC; UNESCOc)  WH_and_Tourism_23_may.indd 70 H_and_Tourism_23_may.indd 70 24/05/2016 05:26 4/05/2016 05:26 (GLOFs), with potentially disastrous impacts on   nearby communities (Portocarrero 2011). | Adapt-MitigImpacts | 72 - 73 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Sea-level rise, increased storm frequency and   intensity, and coastal erosion are major threats   to coastal heritage throughout the UK. Some   17 per cent of the UK's coast is eroding and storm   damage is expected to increase (Masselink and   Russell 2013). Scotland has northern Europe's   longest coastline aside from Norway, and   conservative estimates suggest that 12 per cent   of it is eroding. Of 11 500 archaeological and   historic sites surveyed between 1996 and 2011, nearly a third were assessed as needing some   sort of action or protection (Dawson 2013). | Adapt-MitigImpacts | 81 - 81 |

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| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Archives at risk In Scotland, although Skara Brae is safe for the moment, many other archaeological sites are at risk of destruction by the sea. The threatened sites contain archives of data that can help inform society about human adaptation to previous changes in climate. If no action is taken, however, these archives will be lost. | Adapt-MitigImpacts | 81 - 81 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | As successful as the protection of the area has been over the years, a number of problems remain for which solutions compatible with the sea's protection goals need to be found. In the long term the most important of these may well be climate change and its expected impacts, a major concern in the Wadden Sea region with numerous studies and scientific papers dedicated to this subject. A number of key issues and potential climate change impacts have been identified, including direct effects of sea-level rise, disturbance of natural processes and loss of habitat for many species. | Adapt-MitigImpacts | 83 - 83 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | WH_and_Tourism_23_may.indd 82 24/05/2016 05:48<br>Europe 83– Recognizing that "climate change and enhanced sea-level rise may seriously impact structure, functions and characteristic biodiversity of the Wadden Sea ecosystem, as well as the safety of the inhabitants of the region", in 2014 the Trilateral Wadden Sea Governmental Meeting adopted the Trilateral Climate Change Adaptation Strategy (CWSS 2014b), the overall goal of which is "to safeguard and promote the qualities and the integrity of the area as a natural and sustainable ecosystem whilst ensuring the safety of the inhabitants and visitors". | Adapt-MitigImpacts | 84 - 85 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | The need to act is both urgent and clear. We must reduce greenhouse gas emissions in line with the Paris Agreement while providing the financial resources, support and expertise necessary to ensure the resilience of World Heritage properties over the long term. A growing body of knowledge, management guidelines and policy tools already exists that can help us achieve these goals. Success will require us to expand our networks and partnerships with local communities and businesses and to encourage the tourism industry to join us in this vital task. | Adapt-Mitig | 7 - 7 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | The concept of World Heritage, and the vital importance of linking natural and human systems and maintaining the balance between the two, is now well understood and supported worldwide. The World Heritage Convention helps bring attention to the world's most iconic and important cultural and natural heritage, provides support for management planning and implementation and monitors the state of conservation of the properties on the list. Inclusion on the World Heritage List can help drive tourism to properties, which if managed in accordance with principles of sustainable development can provide important economic benefits to local communities and national economies. | Adapt-Mitig | 14 - 14 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | 2016). One small step forward has been made since Paris. In February 2016, the Committee on Aviation Environmental Protection of the International Civil Aviation Authority for the first time issued a recommendation for a CO2 emissions standard for aircraft that could be strengthened over time (ICAO 2016). | Adapt-Mitig | 20 - 20 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | A recent study by the US National Park Service of the historical correlations between temperature and its 270 million annual visits showed that there is a strong relationship between climate conditions and park visitation. The study showed that park visits tend to increase with warmer weather, but that at temperatures of 25ºC or above they significantly decrease. The authors suggest that climate change will have a large and potentially quite complex role in altering visitation patterns at protected areas worldwide and that managers need to take this into account in management and adaptation planning (Fisichelli et al. 2015). | Adapt-Mitig | 21 - 21 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Adaptation capacity in the tourism sector will vary. It is likely to be especially hard for communities and operators with large investments Changes in populations of fynbos pollinating species, such as this Cape sugarbird feeding on a king protea, could have major implications for the ecosystems of the Cape Floral Region Protected Areas of South Africa. | Adapt-Mitig | 21 - 21 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | World Heritage and tourism in a changing climate 19– WH_and_Tourism_23_may.indd 19 H_and_Tourism_23_may.indd 19 24/05/2016 05:25 4/05/2016 05:25<br>20 World Heritage and Tourism in a Changing Climate in infrastructure such as hotels, resorts, harbours and airports. These could become stranded assets, especially in heavily affected coastal areas. For all destinations, disaster preparedness and management will become an increasingly important part of any destination's integrated management plans as climate-related disasters worsen. Least developed countries, however, are more vulnerable to extreme events than richer ones, and so liable to suffer more. | Adapt-Mitig | 21 - 22 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Almost all World Heritage sites are or become tourist destinations – some are among the most iconic places on Earth – and the objective of the World Heritage Convention is to protect sites of outstanding universal value for future generations. States Parties are required to "present" World Heritage properties to the public, and the inscription of a site on the World Heritage List brings responsibilities for protection as well as opportunities for community and economic progress through sustainable development (WHC 2010). | Adapt-Mitig | 22 - 22 |

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| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | At its General Assembly meeting in Mexico in 1999, ICOMOS adopted the International Cultural Tourism Charter (ICOMOS 1999) with the objective of improving the relationship between host communities and the tourism industry. The charter principles, whilst not specifically designed for World Heritage sites, address some relevant management issues that can provide important guidance at the site level, for example on sensitivity to the needs of local communities, managing potential conflicts, site interpretation and tourism promotion. | Adapt-Mitig | 24 - 24 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Because of their international designation and the resulting resources and attention they receive, World Heritage sites have the potential to provide some of the best models and innovative examples of sustainable tourism. In order to realize that potential, however, and preserve the OUV that defines sites as so transcendentally important for future generations, sustainable and adaptive management strategies should be instituted to help make sites more resilient to climate change. | Adapt-Mitig | 24 - 24 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | UNESCO has produced a practical guide on climate change adaptation for natural World Heritage sites to help site managers better understand how climate change may affect the OUV of the sites and offer ideas for adapting to climate change with tailored management responses (Perry and Falzon 2014). Governments, too, are beginning to integrate climate issues with tourism planning. The best of these strategies have been collaboratively developed by protected area managers, scientists and public and private tourism stakeholders working together (GBRMPA 2009). | Adapt-Mitig | 24 - 24 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Gender issues in global tourism and climate change response at World Heritage sites Gender equality is one of UNESCO’s two global priorities (Olsson et al. 2014; WHO 2011). As women make up a large proportion of the tourism workforce, their full and equal involvement in climate preparedness and management strategies WH_and_Tourism_23_may.indd 22 H_and_Tourism_23_may.indd 22 24/05/2016 05:25 4/05/2016 05:25<br>associated with World Heritage sites and tourism destinations is vital. Even though women in tourism earn 10–15 per cent less on average than their male counterparts (UNWTO 2011), tourism can still offer them significant economic and leadership opportunities. The sector has almost twice as many female employers as any other economic sector, as well as a much higher proportion of self-employed women working on their own (UNWTO 2011). | Adapt-Mitig | 24 - 25 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Indigenous and local knowledge and cultural traditions can contribute to climate resilience There is widespread recognition that indigenous and local populations have unique and valuable local knowledge, traditions and cultural practices that can contribute to effective management strategies in the face of rapid climatic change. | Adapt-Mitig | 26 - 26 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Living cultural heritage is a vital resource for climate adaptation in and around World Heritage sites, and some aspects, including arts and crafts, dances and traditional agricultural practices, are increasingly popular draws for tourists, too. | Adapt-Mitig | 26 - 26 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Many communities living in and around World Heritage sites, however, have developed a wealth of intangible cultural heritage in the form of knowledge and traditions associated with the sustainable management of biodiversity, forests, wetlands and marine resources, often over hundreds or even thousands of years. | Adapt-Mitig | 26 - 26 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Drawing on knowledge built up over generations, local community members can often observe and interpret climate phenomena in a different way, and at a richer and finer scale than can be done by scientists (Goswami 2015). It is commonplace for such traditional knowledge to be overlooked or ignored in planning and administrative decisions. There is, however, a growing number of World Heritage sites where local knowledge and community-based decision making are providing new models of resilience and adaptation. On the Pacific Island of Vanuatu, for example, traditional subsistence and construction practices, along with support networks based on kinship and exchange, form the foundation of cyclone preparedness and response strategies for the nation’s sole World Heritage property, Chief Roi Mata’s Domain (Ballard et al. 2015). | Adapt-Mitig | 26 - 26 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | The practical experience deriving from the Community Management of Protected Areas for Conservation (COMPACT) initiative at several other World Heritage sites – including Tanzania’s Mount Kilimanjaro and the Belize Barrier Reef – demonstrates that the involvement of indigenous peoples and local communities leads to management effectiveness and improved governance (Brown and Hay-Edie 2014). | Adapt-Mitig | 26 - 26 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | All of the case study sites are nationally or regionally important for tourism, and several of them are iconic global tourist destinations, including the Galápagos Islands, Ecuador; Venice and its Lagoon, Italy; and Yellowstone National Park, USA. In addition to the case studies, the report includes information on 18 more World Heritage sites where climate change and tourism management issues interact and for which short sketches are provided to give a broader view of the situation around the world. Together, these provide a sample of World Heritage sites – with a range of low, medium and high levels of tourism development in 29 countries – that are already being affected by climate change or are likely to be highly vulnerable to it in the near future. | Adapt-Mitig | 27 - 27 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | To put these cases in context, the amount available to States Parties requiring international assistance to support site management through the World Heritage Fund totals just US$ 4 million – a drop in the ocean given the scale of response needed for the challenge of climate change. | Adapt-Mitig | 28 - 28 |

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| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Whilst several case-study sites have robust and successful visitor management strategies, few have attempted to comprehensively integrate both climate change and tourism into long-term sustainability planning. The conservation strategy for the Wadden Sea, along the coasts of Denmark, Germany and the Netherlands, provides one of the best examples of this philosophy in action. | Adapt-Mitig | 28 - 28 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | To strengthen resilience to climate change, increase the inclusion of wilderness areas on the World Heritage List, ensure connectivity between sites, and increase resources for protected area management Protecting large intact ecosystems is the most effective way of maintaining the adaptive capacity of natural World Heritage sites. For existing sites this means putting greater emphasis on expanding and managing buffer zones and on ensuring connectivity between sites and other protected areas (Kormos et al. 2015). Increasing the inclusion of wilderness areas with outstanding universal value within the World Heritage Convention will help maintain the large-scale ecosystem processes and biological diversity that are essential for adaptation and resilience in a changing climate and for maintaining the integrity of many sites (Kormos et al. 2015). Governments with protected areas already inscribed on the World Heritage List should step up implementation of existing management plans and policies already established under the World Heritage Convention or other multilateral agreements such as the Ramsar Convention on Wetlands and the Convention on Biological Diversity (Watson et al. | Adapt-Mitig | 30 - 30 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Urgently address the issue of inadequate resourcing for World Heritage site management and climate adaptation Inadequate resourcing is the leading cause of poor performance in protected area management (Watson et al. 2014). Lack of resources, including financing, personnel, training and capacity building, represents the greatest barrier preventing effective management of World Heritage sites, including the assessment of their vulnerability to climate change, developing and implementing climate adaptation and resilience strategies, and planning and managing tourism development. Until World Heritage sites receive adequate public- and private�sector funding and resources, they will struggle to meet their preservation objectives. The tourism industry can demonstrate leadership by developing and participating in innovative partnerships that bring new financing in support of World Heritage site management. | Adapt-Mitig | 30 - 30 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | In view of limitations on human and financial capacity in many developing countries, the task of managing and monitoring World Heritage sites will need to be widened to other sectors such as tourism. The use of innovative and layered approaches involving multiple partners and stakeholders pooling their talents and resources will improve short- and long-term planning, and strengthen monitoring and protection efforts. The coordination capacity of national World Heritage authorities will also require assistance and support from key tourism stakeholders. In particular, tourism promoters and management agencies must be tasked with raising the levels of awareness in their value chains of the vulnerabilities of World Heritage sites and encouraging a coordinated response. | Adapt-Mitig | 32 - 32 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Develop tourism investment guidelines that encourage inclusive and equitable development The development of tourism in and around World Heritage sites should be accompanied by inclusive and equitable economic investment policies (UNESCO 2015). Efforts should also be made to ensure that local communities share equitably in the economic benefits of tourism and that a portion of revenues is re-invested in the management of World Heritage sites and their resilience to climate change. The Community Management of Protected Areas for Conservation (COMPACT) initiative provides a concrete method WH_and_Tourism_23_may.indd 30 H_and_Tourism_23_may.indd 30 24/05/2016 05:25 4/05/2016 05:25<br>and examples for establishing benefit-share programmes for World Heritage sites (Brown and Hay-Edie 2014). | Adapt-Mitig | 32 - 33 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Ensure that indigenous peoples and local communities are fully involved at all stages of climate adaptation and tourism development Utilizing local and traditional knowledge systems for effective adaptation of World Heritage sites is vital in the face of climate change. It is also essential to empower and support local descendent and traditional communities to maintain and preserve what they value, including intangible heritage and subsistence lifestyles (UCSUSA 2014). | Adapt-Mitig | 34 - 34 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Indigenous peoples and local communities should be fully involved and their rights recognized in planning for climate adaptation and sustainable tourism development (AAA 2015; UNESCO 2015). | Adapt-Mitig | 34 - 34 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | This ensures that adaptation strategies contribute to the well-being of the communities, including marginalized groups, and avoids widening existing inequalities (Perry and Falzon 2014). | Adapt-Mitig | 34 - 34 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Increase collaboration on site management planning and operations with tourism stakeholders Where relevant, collaboration with the tourism sector should be a priority for site managers, with attention given to controlling visitor levels and joint activities aimed at conveying accurate information about the site’s OUV. Using certification tools such as ISO14001, the Global Sustainable Tourism Criteria and other sustainability standards can strengthen site management planning and operations. | Adapt-Mitig | 34 - 34 |

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| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Minaret and Archaeological Remains of Jam, Afghanistan WH_and_Tourism_23_may.indd 32 H_and_Tourism_23_may.indd 32 24/05/2016 05:25 4/05/2016 05:25 Case studies WH_and_Tourism_23_may.indd 33 H_and_Tourism_23_may.indd 33 24/05/2016 05:25 4/05/2016 05:25 34 World Heritage & Tourism in a Changing Climate J ust under half of the world's remaining endangered 880 mountain gorillas (Gorilla beringei beringei) live in southwestern Uganda's Bwindi Impenetrable Forest National Park (IGCC 2011). Gorillas are iconic and their populations here and in their other stronghold in the Virunga Mountains on the borders of Uganda, Rwanda and the Democratic Republic of Congo, have been increasing in recent decades as a result of effective forest management and protection strategies (IGCC 2011). These efforts have been helped by revenue from gorilla tourism in both Rwanda and Uganda. | Adapt-Mitig | 34 - 36 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | All indications are that rising temperatures and changes in rainfall regimes will increase stress on gorilla populations, exacerbating the immediate threats posed by habitat degradation, rising tourism and the proximity of rural communities and their expanding populations. Effective ongoing management of Bwindi Impenetrable National Park, its buffer zones and other protected areas as core areas for gorilla conservation is an essential conservation strategy. To support this, it will be vital to maintain the flow of tourism dollars to conservation programmes and local communities. | Adapt-Mitig | 39 - 39 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | It is clear that future prospects for this important biodiversity hotspot and tourism centre will be under pressure in an increasingly warm and dry climate. Preservation of the fynbos biome and its extraordinary array of species will depend on careful management of buffer areas, reduced stress from wildland conversion and perhaps increased connectivity of protected areas, even if global mean temperature increase can be kept to 2ºC or below. | Adapt-Mitig | 43 - 43 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | Plan 4C's vision states: "by the year 2040, the historic heritage of Cartagena de Indias will be resilient to climate change. This will be made possible by carrying out actions within the framework of climate compatible development, maintaining its value as a World Heritage City and a Cultural Interest Asset for the people of Cartagena and visitors" (OMCI et al. 2014). The plan outlines key measures needed to achieve this vision, among which is the protection of assets of cultural interest, revitalization of public spaces, development of sustainable transport, promotion of energy efficiency, and adoption of land management and financial instruments. As outlined in the plan, historic heritage protection entails both mitigation and adaptation strategies. | Adapt-Mitig | 65 - 65 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | The adaptation strategies include the development of a work plan for cultural asset protection to prevent flooding in the historic centre, as well as for the restoration and preservation of buildings. | Adapt-Mitig | 65 - 65 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | First colonized by Ecuador in 1832 and most famously visited by Charles Darwin in 1835, the islands are known worldwide for the role their species, particularly the finches (Fringillidae), played in helping Darwin form his theory of evolution by natural selection. The islands are now one of the world's hotspots for wildlife tourism and are struggling to balance increasing visitor numbers and infrastructure development with conservation imperatives. | Adapt-Mitig | 66 - 66 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | The original management plan of 1973 established a maximum of 12 000 visitors per year, but that has been constantly revised upwards and, in 2013, 205 000 people visited the islands (Parque Nacional Galápagos). Galápagos tourism generates US$ 418 million annually, of which US$ 61 million enters the local economy, fully 51 per cent of the islands' revenue (Galápagos Conservancy a). The resident population of the islands was around 4 000 in the 1970s, but demand for visitor services has been a big driver of rapid growth – the population doubled between 1991 and 2005 and today it stands at around 25 000 people (Galápagos Conservancy b). | Adapt-Mitig | 66 - 66 |
| UNESCO | World Heritage and Tourism in a Changing Climate - UNESCO 2016 | In 2015, initial thoughts about how to prepare for accelerating sea-level rise and identify the right steps for action were developed in more detail for the Schleswig-Holstein part of the Wadden Sea, covering about one third of its entirety. The regional government adopted the Strategy for the Wadden Sea 2100 (MELUR-SH 2015), which had been developed by a stakeholder group consisting of the coastal defence and national park administrations, and representatives from the island communities and two environmental non-governmental organizations including the global conservation organization WWF. | Adapt-Mitig | 85 - 85 |

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| IPCC | WGIIAR5-PartA_FINAL | Examples include greater likelihood of injury, disease, and death due to more intense heat waves and fires (very high confidence); increased likelihood of under-nutrition resulting from diminished food production in poor regions (high confidence); risks from lost work capacity and reduced labor productivity in vulnerable populations; and increased risks from food- and water-borne diseases (very high confidence) and Summary for Policymakers 57 9.3, 25.9, 26.8, 28.2, 28.4, Box 25-5 58 3.5, 10.2, 10.7, 10.10, 17.4-5, 25.7, 26.7-9, Box 25-7 59 Disaster loss estimates are lower-bound estimates because many impacts, such as loss of human lives, cultural heritage, and ecosystem services, are difficult to value and monetize, and thus they are poorly reflected in estimates of losses. Impacts on the informal or undocumented economy as well as indirect economic effects can be very important in some areas and sectors, but are generally not counted in reported estimates of losses. [SREX 4.5] 60 1 tonne of carbon = 3.667 tonne of CO2 61 10.9<br>SPM Summary for Policymakers 20 vector-borne diseases (medium confidence). Positive effects are expected to include modest reductions in cold-related mortality and morbidity in some areas due to fewer cold extremes (low confidence), geographical shifts in food production (medium confidence), and reduced capacity of vectors to transmit some diseases. But globally over the 21st century, the magnitude and severity of negative impacts are projected to increasingly outweigh positive impacts (high confidence). The most effective vulnerability reduction measures for health in the near term are programs that implement and improve basic public health measures such as provision of clean water and sanitation, secure essential health care including vaccination and child health services, increase capacity for disaster preparedness and response, and alleviate poverty (very high confidence). By 2100 for the high-emission scenario RCP8.5, the combination of high temperature and humidity in some areas for parts of the year is projected to compromise normal human activities, including growing food or working outdoors (high confidence). | Heritage | 37 - 38 |
| IPCC | WGIIAR5-PartA_FINAL | Destruction of livelihoods particularly for those depending on water�intensive agriculture. Risk of food insecurity Interactions across human vulnerabilities: deteriorating livelihoods, poverty traps, heightened food insecurity, decreased land productivity, rural outmigration, and increase in new urban poor in developing countries. Potential tipping point in rain�fed farming system and /or pastoralism Limited ability to compensate for losses in water�dependent farming and pastoral systems, and conffict over natural resources Lack of capacity and resilience in water management regimes, inappropriate land policy, and misperception and undermining of pastoral livelihoods vii Rising ocean temperature, ocean acidiffcation, and loss of Arctic sea ice [5.4.2, 6.3.1, 6.3.2, 7.4.2, 9.3.5, 22.3.2, 24.4, 25.6, 27.3.3, 28.2, 28.3, 29.3.1, 30.5, 30.6, Boxes CC-OA and CC-CR;WGI AR5 11.3.3] High susceptibility of warm-water coral reefs and respective ecosystem services for coastal communities; high susceptibility of polar systems, e.g., to invasive species Loss of coral cover, Arctic species, and associated ecosystems with reduction of biodiversity and potential losses of important ecosystem services. Risk of loss of endemic species, mixing of ecosystem types, and increased dominance of invasive organisms Interactions of stressors such as acidiffcation and warming on calcareous organisms enhancing risk Susceptibility of coastal and SIDS ffshing communities depending on these ecosystem services; and of Arctic settlements and culture viii Rising land temperatures, and changes in precipitation patterns and in frequency and intensity of extreme heat [4.3.4, 19.3.2, 22.4.5, 27.3, Boxes 23-1 and CC-WE;WGI AR5 11.3.2] Susceptibility of human systems, agro-ecosystems, and natural ecosystems to (1) loss of regulation of pests and diseases, ffre, landslide, erosion, ffooding, avalanche, water quality, and local climate; (2) loss of provision of food, livestock, ffber, and bioenergy; (3) loss of recreation, tourism, aesthetic and heritage values, and biodiversity Reduction of biodiversity and potential losses of important ecosystem services. Risk of loss of endemic species, mixing of ecosystem types, and increased dominance of invasive organisms Interaction of social-ecological systems with loss of ecosystem services on which they depend Table TS.3 (continued) Social vulnerability Economic vulnerability Environmental vulnerability Institutional vulnerability Exposure<br>61 Technical Summary TS Box TS.5 \| Human Interference with the Climate System Human inffuence on the climate system is clear (WGI AR5 SPM Section D.3;WGI AR5 Sections 2.2, 6.3, 10.3 to 10.6, 10.9). Yet determining whether such inffuence constitutes “dangerous anthropogenic interference” in the words of Article 2 of the UNFCCC involves both risk assessment and value judgments. Scientiffc assessment can characterize risks based on the likelihood, magnitude, and scope of potential consequences of climate change. Science can also evaluate risks varying spatially and temporally across alternative development pathways, which affect vulnerability, exposure, and level of climate change. Interpreting the potential danger of risks, however, also requires value judgments by people with differing goals and worldviews. Judgments about the risks of climate change depend on the relative importance ascribed to economic versus ecosystem assets, to the present versus the future, and to the distribution versus aggregation of impacts. From some perspectives, isolated or infrequent impacts from climate change may not rise to the level of dangerous anthropogenic interference, but accumulation of the same kinds of impacts could, as they become more widespread, more frequent, or more severe. The rate of climate change can also inffuence risks. This report assesses risks across contexts and through time, providing a basis for judgments about the level of climate change at which risks become dangerous. | Heritage | 78 - 79 |
| IPCC | WGIIAR5-PartA_FINAL | 3.5.2.5. Other Uses In addition to direct impacts, vulnerabilities, and risks in water-related sectors, indirect impacts of hydrological changes are expected for navigation, transportation, tourism, and urban planning (Pinter et al., 2006; Koetse and Rietveld, 2009; Rabassa, 2009; Badjeck et al., 2010; Beniston, 2012). Social and political problemscan result from hydrological changes. For example, water scarcity and water overexploitation may increase the risks of violent conflicts and nation-state instability (Barnett and Adger, 2007; Burke et al. 2009; Buhaug et al., 2010; Hsiang et al., 2011). Snowline rise and glacier shrinkage are very likely to impact environmental, hydrological, geomorphological, heritage, and tourism resources in cold regions (Rabassa, 2009), as already observed for tourism in the European Alps (Beniston, 2012).Although most impacts will be adverse, some might be beneficial. | Heritage | 271 - 271 |

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| IPCC | WGIIAR5-PartA_FINAL | 4.3.4. Impacts on Key Ecosystem Services Ecosystem services are the benefits that people derive from ecosystems (see Glossary). Many ecosystem services are plausibly vulnerable to climate change. The Millennium Ecosystem Assessment classification (Millennium Ecosystem Assessment, 2003) recognizes provisioning services such as food (Chapter 7), fiber (Section 4.3.4.2), bioenergy (Section 4.3.4.3), and water (Chapter 3); regulating services such as climate regulation (Section 4.3.4.5), pollination, pest and disease control (Section 4.3.4.4), and flood control (Chapter 3);supporting services such as primary production (Section 4.3.2.2) and nutrient cycling (Section 4.2.4.2, and indirectly Section 4.3.2.3); and cultural services, including recreation and aesthetic and spiritual benefits (Section 10.6). Section 4.3.4.1 focuses on ecosystem services not already covered in the sections referenced above. | Heritage | 337 - 337 |
| IPCC | WGIIAR5-PartA_FINAL | For many locations, population and assets exposure is growing faster than the national average trends owing to coastward migration,coastal industrialization, and urbanization (e.g., McGranahan et al., 2007; Seto, 2011; Smith, 2011; see also Chapter 8; high confidence). Coastal net migration has largely taken place in flood- and cyclone-prone areas, which poses a challenge for adaptation (de Sherbinin et al., 2011).These processes and associated land use changes are driven by a combination of many social, economic, and institutional factors including taxes, subsidies, insurance schemes, aesthetic and recreational attractiveness of the coast, and increased mobility (Bagstad et al., 2007; Palmer et al., 2011). In China, the country with the largest exposed population, urbanization and land reclamation are the major drivers of coastal land use change (Zhu et al., 2012). Although coastal migration is expected to continue in the coming decades, it is difficult to capture this process in global scenarios, as the drivers of migration and urbanization are complex and variable (Black et al., 2011). | Heritage | 391 - 391 |
| IPCC | WGIIAR5-PartA_FINAL | 5.4.3. Human Systems 5.4.3.1. Human Settlements Important direct effects ofclimate change on coastal settlements include dry-land loss due to erosion and submergence, damage of extreme events (such as wind storms, storm surges, floods, heat extremes, and droughts) on built environments, effects on health (food- and water-borne disease), effects on energy use, effects on water availability and resources, and loss ofcultural heritage (Hunt andWatkiss, 2010). SinceAR4, a large number of regional, national, and subnational scale studies on coastal impacts have been conducted. These are covered in the respective regional chapters. At the global scale, studies have focused either on exposure to sea level rise or extreme water levels or on the physical impacts of flooding, submergence, and erosion. | Heritage | 399 - 399 |
| IPCC | WGIIAR5-PartA_FINAL | 5.5.3.2. Institution and Governance Analysis Decisions are made within a context. Institution and governance analysis comprise a variety of approaches that aim at describing this context as well as at explaining the emergence and performance of institutions and governance structures (GS). Institution analysis is particularly relevant to coastal adaptation, because deciding between options and implementing them is an ongoing process involving complex inter�linkages between public and private decisions at multiple levels of decision making and in the context of other issues, existing policies, conflicting interests, and diverse GS (e.g, Few et al., 2007; Urwin and Jordan, 2008; Hinkel et al., 2010; see also Sections 2.2.2, 2.2.3). The non-consideration of this context may hinder or mislead adaptation decisions and implementations as reported by the emerging literature on barriers to adaptation (Section 5.5.5). Institution analysis strives to understand how this context shapes decisions, and insights gained may be employed to craft effective institutions and policies for adaptation. | Heritage | 406 - 406 |
| IPCC | WGIIAR5-PartA_FINAL | Regarding natural (unassisted) adaptation, several researchers have examined biophysical limits, for example, of coastal marshes (Craft et al., 2009; Langley et al., 2009; Mudd et al., 2009; Kirwan et al., 2010), and found that under certain nonlinear feedbacks among inundation, plant growth, organic matter accretion, and sediment deposition coastal wetlands can adapt to conservative rates of sea level rise (SRES A1B) if suspended sediment surpasses a certain threshold. In contrast, even coastal marshes with high sediment supplies will submerge near the<br>394 Chapter 5 Coastal Systems and Low-Lying Areas 5 end of the 21st century under scenarios of more rapid sea level rise (e.g., those that include ice sheet melting). | Heritage | 411 - 412 |
| IPCC | WGIIAR5-PartA_FINAL | 6.4.1. Ecosystem Services Marine ecosystem services (e.g., Chapter 5) include products (food, fuel, biochemical resources), climate regulation and biogeochemical processes (CO2 uptake, carbon storage, microbial water purification), coastal protection, provision of space and waterways for maritime transport, cultural services (recreational and spiritual opportunities, aesthetic enjoyment), and functions supporting all other ecosystem services (nutrient cycling, photosynthesis, habitat creation). Most components of the marine environment contribute to more than one major category of ecosystem service: for example, ocean primary productivity isclassified as a supporting service, but it affects provisioning services via changes in fisheries, generation of fossil fuel resources, regulating services via the global carbon cycle and climate regulation, and cultural services via the enjoyment of a healthy ecosystem. Rarely has economic damage of climate change to a whole ecosystem been evaluated and projected. The projected loss of tropical reef cover due to ocean acidification under SRESA1 and B2 scenarios will cause damages of US$870 and 528 billion (year 2000 value) by 2100, respectively (cost rising with parallel economic growth; Brander et al., 2012;see also Box CC-OA). Such loss is felt most strongly in the respective regions. | Heritage | 470 - 470 |
| IPCC | WGIIAR5-PartA_FINAL | Climate change may endanger harvests of marine species with spiritual and aesthetic importance to indigenous cultures, raising ethical questions about cultural preservation (e.g., Nuttall, 1998). In coastal communities, losing the aesthetic values of marine ecosystems may harm local economies: better water quality and fewer harmful algal blooms are related to higher shellfish landings and real estate prices (Jin et al., 2008). | Heritage | 471 - 471 |
| IPCC | WGIIAR5-PartA_FINAL | Some heritage benefits of preserving marine ecosystems consist of the economic value of a healthy, diverse ecosystem to future generations. | Heritage | 471 - 471 |

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| IPCC | WGIIAR5-PartA_FINAL | Any climate-related biodiversity loss or pollution of marine ecosystems would decrease the bank of resources for future opportunities. For example, the research and conservation value of coral reef biodiversity and its non-use value are estimated together at US$5.5 billion annually (Cesar et al., 2003).As with spiritual and aesthetic benefits, maintaining heritage benefits under climate change poses challenges for managers concerning equity and ethics as well as multigenerational (and possibly multi-cultural) ethical questions. | Heritage | 471 - 471 |
| IPCC | WGIIAR5-PartA_FINAL | 8.2.4.4. Built Environment, and Recreation and Heritage Sites Housing ideally provides its occupants with a comfortable, healthy, and secure living environment and protects them from injuries, losses, damage, and displacement (Haines et al., 2013). For many low-income households, livelihoods also depend on home-based enterprises, and housing is key to protecting their assets and preventing disruption of their incomes. Decent housing has particular importance for vulnerable groups, including infants and young children (Bartlett, 2008), older residents, or those with disabilities or chronic health conditions. | Heritage | 577 - 577 |
| IPCC | WGIIAR5-PartA_FINAL | The increased risks that climate change brings to the built environment (Spennemann and Look, 1998;Wilby, 2007) also apply to built heritage. | Heritage | 578 - 578 |
| IPCC | WGIIAR5-PartA_FINAL | This has led to the Venice Declaration on Building Resilience at the Local Level Towards Protected Cultural Heritage and Climate Change Adaptation Strategies,which brings together UNESCO, UN-HABITAT, EC, and individual city mayors. An example is Saint-Louis in Senegal, a coastal city and World Heritage Site on the mouth of the Senegal river, which has frequent floods and large areas at risk from river and coastal flooding. There are initiatives to reduce flooding risks and relocate families from locations most at risk, but the local authority has very limited investment capacity (Diagne, 2007; Silver et al., 2013). | Heritage | 578 - 578 |
| IPCC | WGIIAR5-PartA_FINAL | Spennemann, D.H.R. and D.W. Look (eds.), 1998: Disaster Management Programs for Historic Sites. Proceedings of a symposium organized by the U.S. National Park Service,Western Regional Office, San Francisco, CA in collaboration with the Western Chapter of the Association for Preservation Technology held June 27 – 29, 1997 in San Francisco, CA, Western Chapter of the Association for Preservation Technology, San Francisco, CA, USA, U.S. National Park Service, and The Johnstone Centre of Parks, Recreation, and Heritage at Charles Sturt University,Albury,Australia, U.S. Government Printing Office,Washington, DC, USA, 195 pp. | Heritage | 627 - 627 |
| IPCC | WGIIAR5-PartA_FINAL | (2009) note that climate change may require a greater effort to protect cultural heritage. Chapter 12 discusses the impact of climate change on violent conflict, which has implications for military expenditures. | Heritage | 705 - 705 |
| IPCC | WGIIAR5-PartA_FINAL | Loss of land, cultural and natural heritage disrupting cultural practices embedded in livelihoods and expressed in narratives, world views, identity, community cohesion, and sense of place (high conffdence) [12.3.2, 12.3.4] Cultural values and expressions are dynamic and inherently adaptable and hence adaptation is possible to avoid losses of cultural assets and expressions. Nevertheless cultural integrity will be compromised in these circumstances. | Heritage | 796 - 796 |
| IPCC | WGIIAR5-PartA_FINAL | Climate change Globalizations Technological change<br>800 Chapter 13 Livelihoods and Poverty 13 in multiple domains that promote opportunities and empowerment, and enhance security (World Bank, 2001). In addition to material deprivation, multidimensional conceptions of poverty consider a sense of belonging and socio-cultural heritage (O'Brien and Leichenko, 2003), identity, and agency, or “the culturally constrained capacity to act” (Ahearn, 2001, p. 54). The AR4 identified poverty as “the most serious obstacle to effective adaptation” (Confalonieri et al., 2007, p. 417). | Heritage | 817 - 818 |
| IPCC | WGIIAR5-PartA_FINAL | Application of cost-benefit or real option analysis requires evaluations in monetary terms. For market impacts, prices may need to be corrected for policies, monopoly power, or other external factors distorting market prices (Squire and van der Tak, 1975). But a cost-benefit analysis also often requires the valuation of non-market costs and benefits. This is the case for impacts on public health, cultural heritage, environmental quality and ecosystems, and distributional impacts. Valuation of non�market impact is difficult because of values and preferences heterogeneity, and subject to controversies—for example, on the value to attribute to avoided death (see Viscusi and Aldy, 2003). | Heritage | 974 - 974 |

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| IPCC | WGIIAR5-PartA_FINAL | Loss ofArctic sea ice and degradation of coral reefs, as well as other natural barriers, presents a high risk to ecosystem services where many people are exposed to coastal hazards and also depend on coastal resources for livelihoods, such as Alaska, the Philippines, and Indonesia (WGI AR5 Section 11.3.3; Sections 5.4.2, 6.3.1-2, 7.4.2, 9.3.5, 22.3.2.3, 24.4, 25.6, 27.3.3, 28.2-3, 29.3.1, 30.5-6; Boxes CC-OA, CC-CR). [RFC 1, 2, and 4] viii) Risk of loss of terrestrial and inland water ecosystems, biodiversity, and the ecosystem goods, functions, and services they provide for livelihoods. Biodiversity and terrestrial ecosystem services are important for rural and urban communities globally. These services are at risk due to rising temperatures, changes in precipitation patterns, and extreme weather events. Risks are high forcommunities whose livelihoods depend on provisioning services. Human and natural systems are susceptible to loss of provisioning services such as food and fiber, regulating services such as water quality, fire, and erosion, and cultural services such as aesthetic values and tourism (WGI AR5 Section 11.3.2.5; Sections 4.3.4, 19.3.2.1, 22.4.5.6, 27.3.2.1; Boxes 23-1, CC-WE; FAQs 4.5, 4.7). [RFC 1, 3 and 4] An important common characteristic of all key risks associated with anthropogenicclimate change isthat they are determined by hazards due to changing climatic conditions on the one hand and the vulnerability of exposed societies, communities, and social-ecological systems, for No. Hazard Key vulnerabilities Key risks Emergent risks vi Drought (WGI AR5 Sections 12.4.1 and 12.4.5; Sections 3.2.7, 3.4.8, 3.5.1, 8.2.3, 8.2.4, 9.3.3, 9.3.5, 13.2.1, 19.3.2.2, and 24.4) Urban populations with inadequate water services. | Heritage | 1089 - 1089 |
| IPCC | WGIIAR5-PartA_FINAL | Risk of loss of endemic species, mixing of ecosystem types, and increased dominance of invasive organisms Interaction of social-ecological systems with loss of ecosystem services upon which they depend Susceptibility of human systems, agro-ecosystems, and natural ecosystems to (1) loss of regulation of pests and diseases, ffre, landslide, erosion, ffooding, avalanche, water quality, and local climate; (2) loss of provision of food, livestock, ffber, bioenergy; (3) loss of recreation, tourism, aesthetic and heritage values, and biodiversity Social vulnerability Economic vulnerability Environmental vulnerability Institutional vulnerability Exposure Table 19-4 (continued)<br>1072 Chapter 19 Emergent Risks and Key Vulnerabilities 19 example, in terms of livelihoods, infrastructure, ecosystem services and management/governance systems on the other (see Table 19-4). The compilation of key risks underscores that effective adaptation and risk reduction measures would address all three components of risk (high confidence). | Heritage | 1089 - 1090 |
| IPCC | WGIIAR5-PartB_FINAL | {23.5.1} Climate change and sea level rise may damage European cultural heritage, including buildings, local industries, landscapes, archaeological sites, and iconic places (medium confidence), and some cultural landscapes may be lost forever (low confidence). {23.5.4; Table 23-3} Climate change may adversely affect background levels of tropospheric ozone (low confidence; limited evidence, low agreement), assuming no change in emissions, but the implications for future particulate pollution (which is more health-damaging) are very uncertain. {23.6.1} Higher temperatures may have affected trends in ground level tropospheric ozone (low confidence). {23.6.1} Climate change is likely to decrease surface water quality due to higher temperatures and changes in precipitation patterns (medium confidence), {23.6.3} and is likely to increase soil salinity in coastal regions (low confidence). {23.6.2} Climate change may also increase soil erosion (from increased extreme events) and reduce soil fertility (low confidence, limited evidence). {23.6.2}<br>1273 Europe Chapter 23 23 Observed climate change is affecting a wide range of flora and fauna, including plant pests and diseases (high confidence) {23.4.1, 23.4.4, 23.6.4} and the disease vectors and hosts (medium confidence). {23.4.2} Climate change is very likely to cause changes in habitats and species, with local extinctions (high confidence) and continental-scale shifts in species distributions (medium confidence). | Heritage | 148 - 149 |
| IPCC | WGIIAR5-PartB_FINAL | 23.4.5. Bioenergy Production The potential distribution of temperate oilseeds (e.g., oilseed rape, sunflower),starch crops (e.g., potatoes),cereals (e.g., barley), and solid biofuel crops (e.g., sorghum, Miscanthus) is projected to increase in Northern Europe by the 2080s, as a result of increasing temperatures, and to decrease in Southern Europe due to increased drought frequency Box 23-1 \| Assessment of Climate Change Impacts on Ecosystem Services by Sub-region Ecosystems provide a number of vital provisioning, regulating, and cultural services for people and society that ffow from the stock of natural capital (Stoate et al., 2009; Harrison et al., 2010). Provisioning services such as food from agro-ecosystems or timber from forests derive from intensively managed ecosystems; regulating services underpin the functioning of the climate and hydrological systems; and cultural services such as tourism, recreation, and aesthetic value are vital for societal well-being (see Section 23.5.4). | Heritage | 164 - 164 |
| IPCC | WGIIAR5-PartB_FINAL | 23.5.4. Cultural Heritage and Landscapes Climate change will affectculturally valued buildings (Storm et al., 2008) through extreme events and chronic damage to materials (Brimblecombe et al., 2006; Brimblecombe and Grossi, 2010; Brimblecombe, 2010a, 2010b; Grossi et al., 2011; Sabbioni et al., 2012). Cultural heritage is a non-renewable resource and impacts from environmental changes are assessed over long time scales (Brimblecombe and Grossi, 2008, 2009, 2010; Grossi et al., 2008; Bonazza et al., 2009a,b). Climate change may also affect indoor environments where cultural heritage is preserved (Lankester and Brimblecombe, 2010) as well as visitor behavior at heritage sites (Grossi et al., 2010).There is also evidence to suggest that climate change and sea level rise will affect maritime heritage in the form of shipwrecks and other submerged archaeology (Björdal, 2012). | Heritage | 168 - 168 |

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| IPCC | WGIIAR5-PartB_FINAL | Europe has many unique rural landscapes, which reflect the cultural heritage that has evolved from centuries of human intervention, for example,the cork oak based Montado in Portugal,the Garrigue ofsouthern France,Alpine meadows, grouse moors in the UK, machair in Scotland, peatlands in Ireland, the polders of Belgium and the Netherlands, and vineyards. Many, if not all, of these cultural landscapes are sensitive to climate change and even small changes in the climate could have significant impacts (Gifford et al., 2011).Alpine meadows, for example, are culturally important within Europe, but although there is analysis of the economics (tourism, farming) and functionality (water runoff, flooding, and carbon sequestration) of these landscapes there is very little understanding of how climate change will affect the cultural aspects on which local communities depend. Because of their societal value, cultural landscapes are often protected and managed through rural development and environmental policies.The peat-rich uplands of Northern Europe, for example, have begun to consider landscape management as a means of adapting to the effects of climate change (e.g., the moors for the future partnership in the Peak District National Park, UK). For a discussion of the cultural implications of climate change for vineyards, see Box 23-2. | Heritage | 169 - 169 |
| IPCC | WGIIAR5-PartB_FINAL | 23.6.1. Air Quality Climate changewill have complex and local effects on pollution chemistry, transport, emissions, and deposition.Outdoor air pollutants have adverse effects on human health, biodiversity,crop yields, and cultural heritage. | Heritage | 169 - 169 |
| IPCC | WGIIAR5-PartB_FINAL | • The vulnerability ofcultural heritage, including monuments/buildings and cultural landscapes, is an emerging concern. Some cultural landscapes will disappear. Grape production is highly sensitive to climate, but production (of grape varieties) is strongly culturally dependent and adaptation is potentially limited by the regulatory context. | Heritage | 179 - 179 |
| IPCC | WGIIAR5-PartB_FINAL | 25.4. Cross-Sectoral Adaptation: Approaches, Effectiveness, and Constraints 25.4.1. Frameworks, Governance, and Institutional Arrangements Adaptation responses depend heavily on institutional and governance arrangements(see Chapters 2, 14-16, 20). Responsibility for development and implementation of adaptation policy in Australasia is largely devolved to local governments and, in Australia, to State governments and Natural Resource Management bodies. Federal/central government supports adaptation mostly via provision of information,tools, legislation, policy guidance, and (in Australia) support for pilot projects.A standard risk management paradigm has been promoted to embed adaptation into decision-making practices (AGO, 2006; MfE, 2008b; Standards Australia, 2013), but broader systems and resilience approaches are used increasingly for natural resource management (Clayton et al., 2011; NRC, 2012). The Council of Australian Governments agreed a national adaptation policy framework in 2007 (COAG, 2007). This included establishing the collaborative National Climate Change Adaptation Research Facility (NCCARF) in 2008,which complemented Commonwealth Scientific and Industrial Research Organisation (CSIRO)'s Climate Adaptation Flagship. The federal government supported a first-pass nationalcoastal risk assessment (DCC, 2009;DCCEE, 2011), is developing indicators and criteria for assessing adaptation progress and outcomes (DIICCSRTE, 2013), and commissioned targeted reports addressing impacts and management options for natural and managed landscapes (Campbell, 2008; Steffen et al., 2009; Dunlop et al., 2012), National and World Heritage areas (ANU, 2009; BMT WBM, 2011), and indigenous and urban communities (Green et al., 2009; Norman, 2010). Most State and Territory governments have also developed adaptation plans (e.g., DSE, 2013). | Heritage | 258 - 258 |
| IPCC | WGIIAR5-PartB_FINAL | Although multi-level and multi-sectoralcoordination is a key component of effective adaptation, it is constrained by factors such as mismatch between climate and development goals, political rivalry, and lack of national support to regional and local efforts (Brklacich et al., 2008; Brown, 2009; Sander-Regier et al., 2009; Sydneysmith et al., 2010; Craft and Howlett, 2013; Romero-Lankao et al., 2013a). Traditionally, environmental or engineering agencies are responsible forclimate issues (e.g., Mexico City, Edmonton and London, Canada), but have neither the decision-making power nor the resources to address all dimensions involved. Adaptation planning requires long-term investments by government, business, grassroots organizations, and individuals (e.g., Romero-Lankao, 2007; Burch, 2010; Croci et al., 2010; Richardson, 2010). | Heritage | 352 - 352 |
| IPCC | WGIIAR5-PartB_FINAL | In the Caribbean, downscaled climate projections have been generated for some islands using the Hadley Centre PRECIS (Providing REgional Climates for Impact Studies) regional model (Taylor et al., 2007; Stephenson et al., 2008). For the SRES A2 and B2 scenarios, the PRECIS regional climate model projects an increase in temperature across the Caribbean of 1°C to 4°C compared to a 1960–1990 baseline, with increasing rainfall during the latter part of the wetseason from November to January in the northern Caribbean (i.e., north of 22°N) and drier conditions in the southern Caribbean linked to changes in the Caribbean Low Level Jet (CLLJ) with a strong tendency to drying in the traditional wet season from June to October (Whyte et al., 2008; Campbell et al., 2011; Taylor et al., 2013). Projected lengthening seasonal dry periods, and increasing frequency of drought are expected to increase demand for water throughout the region under the SRESA1B scenario (Cashman et al., 2010). Decrease in crop yield is also projected in Puerto Rico for the SRES B1 (low), A2 (mid to high), and A1F1 scenarios during September although increased crop yield is suggested during February (Harmsen et al., 2009). Using a tourism demand model linked to the SRES A1F1, A2, B1, and B2 scenarios, the projected climate change heating and drying impacts are also linked to potential aesthetic, physical, and thermal effects that are estimated to cause a change in total regional tourist expenditure of about +321, +356, –118, and -146 million US$ from the least to the most severe emissions scenario, respectively (Moore, 2010). | Heritage | 504 - 504 |
| IPCC | WGIIAR5-PartB_FINAL | Ecosystem services Ecological processes or functions having monetary or non-monetary value to individuals or society at large. These are frequently classified as (1) supporting services such as productivity or biodiversity maintenance, (2) provisioning services such as food, fiber, or fish, (3) regulating services such as climate regulation or carbon sequestration, and (4) cultural services such as tourism or spiritual and aesthetic appreciation. | Heritage | 640 - 640 |

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| IPCC | ar4_wg2_full_report | Tourism is the major contributor to GDP and employment in  many small islands. Sea-level rise and increased sea-water  temperature are likely to contribute to accelerated beach erosion,  degradation of coral reefs and bleaching (Table TS.2). In  addition, loss of cultural heritage from inundation and flooding  will reduce the amenity value for coastal users. Whereas a  warmer climate could reduce the number of people visiting small  islands in low latitudes, it could have the reverse effect in mid�and high-latitude islands. However, water shortages and  increased incidence of vector-borne diseases are also likely to  deter tourists [16.4.6]. | Heritage | 69 - 69 |
| IPCC | ar4_wg2_full_report | Chacaltaya Glacier, with a mean altitude of 5,260 m above sea level, was the highest skiing station in the world until a very few  years ago. After the accelerated shrinkage of the glacier during the 1990s, enhanced by the warm 1997/98 El Niño, Bolivia lost  its only ski area (Figure 1.1), directly affecting the development of snow sports and recreation in this part of the Andes, where  glaciers are an important part of the cultural heritage. | Heritage | 98 - 98 |
| IPCC | ar4_wg2_full_report | There are major implications for amenities, cultural heritage,  accessibility, and health of communities. These include costs,  injury and trauma due to increased storm intensity and higher  extreme temperatures, damage to items and landscapes of  cultural significance, degraded beaches due to sea-level rise  and larger storm surges, and higher insurance premiums (PIA,  2004). Increased demand for emergency services is likely. By  2100, costs of road maintenance in Australia are estimated to  rise 31% for the SRES A2 scenario in a CSIRO climate  simulation (Austroads, 2004). | Heritage | 533 - 533 |
| IPCC | ar4_wg2_full_report | SOE, 2001: Australia State of the Environment 2001: Independent Report to the  Commonwealth Minister for the Environment and Heritage. Australian State of  the Environment Committee, CSIRO Publishing on behalf of the Department of  the Environment and Heritage, 129 pp. http:/www.ea.gov.au/soe/2001. | Heritage | 549 - 549 |
| IPCC | ar4_wg2_full_report | Tourism is the major contributor to GDP and employment in  many small islands. Sea-level rise and increased sea water  temperature will cause accelerated beach erosion, degradation  of coral reefs, and bleaching. In addition, a loss of cultural  heritage from inundation and flooding reduces the amenity value  for coastal users. Whereas a warmer climate could reduce the  number of people visiting small islands in low latitudes, it could  have the reverse effect in mid- and high-latitude islands. | Heritage | 700 - 700 |
| IPCC | ar4_wg2_full_report | Tourism is a major economic sector in many small islands,  and its importance is increasing. Since their economies depend  so highly on tourism, the impacts of climate change on tourism  resources in small islands will have significant effects, both  direct and indirect (Bigano et al., 2005; Viner, 2006). Sea-level  rise and increased sea water temperatures are projected to  accelerate beach erosion, cause degradation of natural coastal  defences such as mangroves and coral reefs, and result in the  loss of cultural heritage on coasts affected by inundation and  flooding. These impacts will in turn reduce attractions for coastal  tourism. For example, the sustainability of island tourism resorts  in Malaysia is expected to be compromised by rising sea level,  beach erosion and saline contamination of coastal wells, a major  source of water supply for island resorts (Tan and Teh, 2001). | Heritage | 712 - 712 |
| IPCC | ar4_wg2_full_report | Almost without exception, international airports on small  islands are sited on or within a few kilometres of the coast, and  on tiny coral islands. Likewise, the main (and often only) road  network runs along the coast (Walker and Barrie, 2006). In the  South Pacific region of small islands, Lal (2004) estimates that,  since 1950, mean sea level has risen at a rate of approximately  3.5 mm/yr, and he projects a rise of 25 to 58 cm by the middle  of this century. Under these conditions, much of the  Box 16.3. Grenada and Hurricane Ivan  Hurricane Ivan struck Grenada on 7 September 2004, as a category 4 system on the Saffir-Simpson scale. Sustained winds  reached 140 mph, with gusts exceeding 160 mph. An official OECS/UN-ECLAC Assessment reported the following:  • 28 people killed,  • overall damages calculated at twice the current GDP,  • 90% of housing stock damaged,  • 90% of guest rooms in the tourism sector damaged or destroyed, equivalent to approximately 29% GDP,  • losses in telecommunications equivalent to 13% GDP,  • damage to schools and education infrastructure equivalent to 20% GDP,  • losses in agricultural sector equivalent to 10% GDP. The two main crops, nutmeg and cocoa, which have  long gestation periods, will not contribute to GDP or earn foreign exchange for the next 10 years,  • damage to electricity installations totalling 9% GDP,  • heavy damage to eco-tourism and cultural heritage sites, resulting in 60% job losses in the sub-sector,  • prior to Hurricane Ivan, Grenada was on course to experience an economic growth rate of approximately  5.7% per annum but negative growth of around −1.4% per annum is now forecast. | Heritage | 713 - 713 |
| IPCC | ar4_wg2_full_report | (2001) noted that some traditional island assets, including  subsistence and traditional technologies, skills and knowledge,  and community structures, and coastal areas containing spiritual,  cultural and heritage sites, appeared to be at risk from climate  change, and particularly sea-level rise. They argued that some of  these values and traditions are compatible with modern  conservation and environmental practices. | Heritage | 719 - 719 |
| IPCC | ar4_wg2_full_report | This section assesses the limits to adaptation that have been  discussed in the climate change and related literatures. Limits  are defined here as the conditions or factors that render  adaptation ineffective as a response to climate change and are  largely insurmountable. These limits are necessarily subjective  and dependent upon the values of diverse groups. These limits  to adaptation are closely linked to the rate and magnitude of  climate change, as well as associated key vulnerabilities  discussed in Chapter 19. The perceived limits to adaptation are  hence likely to vary according to different metrics. For example,  the five numeraires for judging the significance of climate  change impacts described by Schneider et al. (2000b) - monetary  loss, loss of life, biodiversity loss, distribution and equity, and  quality of life (including factors such as coercion to migrate,  conflict over resources, cultural diversity, and loss of cultural  heritage sites) - can lead to very different assessments of the  limits to adaptation. But emerging literature on adaptation  processes also identifies significant barriers to action in  financial, cultural and policy realms that raise questions about  the efficacy and legitimacy of adaptation as a response to climate  change. | Heritage | 744 - 744 |

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| IPCC | ar4_wg2_full_report | For some impacts, qualitative rankings of magnitude are more appropriate than quantitative ones. Qualitative methods have been applied to reflect social preferences related to the potential loss of cultural or national identity, loss of cultural heritage sites, and loss of biodiversity (Schneider et al., 2000). | Heritage | 796 - 796 |
| IPCC | ar4_wg2_full_report | Ecosystem services Ecological processes or functions having monetary or non-mon�etary value to individuals or society at large. There are (i) sup�porting services such as productivity or biodiversity maintenance, (ii) provisioning services such as food, fibre, or fish, (iii) regulating services such as climate regulation or car�bon sequestration, and (iv) cultural services such as tourism or spiritual and aesthetic appreciation. | Heritage | 885 - 885 |
| IPCC | ar4_wg2_full_report | INTA Usunoff, Eduardo Instituto de Hidrologie de Llanuras Vinocur, Marta Universidad Nacional de Río Cuarto Wehbe, Mónica Universidad Nacional de Río Cuarto AUSTRALIA Anderson, Rod Department of Sustainability and Environment Ash, Andrew CSIRO Baird, Mark University of New South Wales Barnett, Jon The University of Melbourne Beer, Tom CSIRO Appendix III: Reviewers of the IPCC WGII Fourth Assessment Report Beggs, Paul Macquarie University Boyle, Sharon Planning Institute of Australia Brunskill, Gregg Australian Institute of Marine Science Chambers, Lynda Bureau of Meteorology Research Centre Churchman, Susan Department of Environment and Heritage South Cleland, Sam Bureau of Meteorology Cocklin, Chris Monash University Coleman, Anthony Insurance Australia Group Collins, Dean Bureau of Meteorology Crimp, Steven Queensland Centre for Climate Applications Curran, Beth Bureau of Meteorology Dunlop, Michael CSIRO Edwards, Spencer Department of Environment and Heritage Farquhar, Graham Australian National University Garnham, John Department of Primary Industries Gifford, Roger M. | Heritage | 910 - 911 |
| IPCC | IPCC_AR6_WGII_Full_Report | This report recognises the value of diverse forms of knowledge such as scientific, as well as Indigenous knowledge and local knowledge in understanding and evaluating climate adaptation processes and actions to reduce risks from human-induced climate change. AR6 highlights adaptation solutions which are effective, feasible13, and conform to principles of justice14. The term climate justice, while used in different ways in different contexts by different communities, generally includes three principles: distributive justice which refers to the allocation of burdens and benefits among individuals, nations and generations; procedural justice which refers to who decides and participates in decision-making; and recognition which entails basic respect and robust engagement with and fair consideration of diverse cultures and perspectives. | Heritage | 7 - 7 |
| IPCC | IPCC_AR6_WGII_Full_Report | confidence), especially for Indigenous Peoples, small-scale food producers and low-income households (high confidence), with children, elderly people and pregnant women particularly impacted (high confidence). Roughly half of the world's population currently experience severe water scarcity for at least some part of the year due to climatic and non-climatic drivers (medium confidence). (Figure SPM.2b) {3.5, Box 4.1, 4.3, 4.4, 5.2, 5.4, 5.8, 5.9, 5.12, 7.1, 7.2, 9.8, 10.4, 11.3, 12.3, 13.5, 14.4, 14.5, 15.3, 16.2, CCP5.2, CCP6.2} SPM.B.1.4 Climate change has adversely affected physical health of people globally (very high confidence) and mental health of people in the assessed regions (very high confidence). Climate change impacts on health are mediated through natural and human systems, including economic and social conditions and disruptions (high confidence). In all regions extreme heat events have resulted in human mortality and morbidity (very high confidence). The occurrence of climate-related food-borne and water-borne diseases has increased (very high confidence). The incidence of vector-borne diseases has increased from range expansion and/or increased reproduction of disease vectors (high confidence). Animal and human diseases, including zoonoses, are emerging in new areas (high confidence). Water and food-borne disease risks have increased regionally from climate-sensitive aquatic pathogens, including Vibrio spp. (high confidence), and from toxic substances from harmful freshwater cyanobacteria (medium confidence). Although diarrheal diseases have decreased globally, higher temperatures, increased rain and flooding have increased the occurrence of diarrheal diseases, including cholera (very high confidence) and other gastrointestinal infections (high confidence). In assessed regions, some mental health challenges are associated with increasing temperatures (high confidence), trauma from weather and climate extreme events (very high confidence), and loss of livelihoods and culture (high confidence). Increased exposure to wildfire smoke, atmospheric dust, and aeroallergens have been associated with climate-sensitive cardiovascular and respiratory distress (high confidence). Health services have been disrupted by extreme events such as floods (high confidence). {4.3, 5.12, 7.2, Box 7.3, 8.2, 8.3, Figure 8.10, 30 Acute food insecurity can occur at any time with a severity that threatens lives, livelihoods or both, regardless of the causes, context or duration, as a result of shocks risking determinants of food security and nutrition, and used to assess the need for humanitarian action (IPC Global Partners, 2019). APPROVED Summary for Policymakers IPCC WGII Sixth Assessment Report Subject to Copyedit SPM-11 Total pages: 35 Box 8.6, 9.10, Figure 9.33, Figure 9.34, 10.4, 11.3, 12.3, 13.7, 14.4, 14.5, Figure 14.8, 15.3, 16.2, Table CCP5.1, CCP5.2.5, CCP6.2, Figure CCP6.3, Table CCB ILLNESS.1} SPM.B.1.5 In urban settings, observed climate change has caused impacts on human health, livelihoods and key infrastructure (high confidence). Multiple climate and non-climate hazards impact cities, settlements and infrastructure and sometimes coincide, magnifying damage (high confidence). Hot extremes including heatwaves have intensified in cities (high confidence), where they have also aggravated air pollution events (medium confidence) and limited functioning of key infrastructure (high confidence). Observed impacts are concentrated amongst the economically and socially marginalized urban residents, e.g., in informal settlements (high confidence). Infrastructure, including transportation, water, sanitation and energy systems have been compromised by extreme and slow-onset events, with resulting economic losses, disruptions of services and impacts to wellbeing (high confidence). {4.3, 6.2, 7.1, 7.2, 9.9, 10.4, 11.3, 12.3, 13.6, 14.5, 15.3, CCP2.2, CCP4.2, CCP5.2} SPM.B.1.6 Overall adverse economic impacts attributable to climate change, including slow-onset and extreme weather events, have been increasingly identified (medium confidence). Some positive economic effects have been identified in regions that have benefited from lower energy demand as well as comparative advantages in agricultural markets and tourism (high confidence). Economic damages from climate change have been detected in climate-exposed sectors, with regional effects to agriculture, forestry, fishery, energy, and tourism (high confidence), and through outdoor labour productivity (high confidence). Some extreme weather events, such as tropical cyclones, have reduced economic growth in the short-term (high confidence). | Heritage | 12 - 13 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | inequalities. Maladaptation can be avoided by flexible, multi-sectoral, inclusive and long-term planning and implementation of adaptation actions with benefits to many sectors and systems. (high confidence) {1.3, 1.4, 2.6., Box 2.2, 3.2, 3.6, Box 4.3, Box 4.5, 4.6, 4.7, Figure 4.29, 5.6, 5.13, 8.2, 8.3, 8.4, 8.6, 9.6, 9.7, 9.8, 9.9, 9.10, 9.11, Box 9.5, Box 9.8, Box 9.9, Box 11.6, 13.11, 13.3, 13.4, 13.5, 14.5, 15.5, 15.6, 16.3, 17.3, 17.4, 17.6, 17.2, 17.5, CCP5.4, CCB NATURAL, CCB SLR, CCB DEEP, CWGB BIOECONOMY, CCP2.3, CCP2.3} SPM.C.4.1 Actions that focus on sectors and risks in isolation and on short-term gains often lead to maladaptation if long-term impacts of the adaptation option and long-term adaptation commitment are not taken into account (high confidence). The implementation of these maladaptive actions can result in infrastructure and institutions that are inflexible and/or expensive to change (high confidence). For example, seawalls effectively reduce impacts to people and assets in the short-term but can also result in lock-ins and increase exposure to climate risks in the long-term unless they are integrated into a long-term adaptive plan (high confidence). Adaptation integrated with development reduces lock-ins and creates opportunities (e.g., infrastructure upgrading) (medium confidence). {1.4, 3.4, 3.6, 10.4, 11.7, Box 11.6, 13.2, 17.2, 17.5, 17.6, CCP 2.3, CCB SLR, CCB DEEP} SPM.C.4.2 Biodiversity and ecosystem resilience to climate change are decreased by maladaptive actions, which also constrain ecosystem services. Examples of these maladaptive actions for ecosystems include fire suppression in naturally fire-adapted ecosystems or hard defences against flooding. These actions reduce space for natural processes and represent a severe form of maladaptation for the ecosystems they degrade, replace or fragment, thereby reducing their resilience to climate change and the ability to provide ecosystem services for adaptation. Considering biodiversity and autonomous adaptation in long-term planning processes reduces the risk of maladaptation. (high confidence) {2.4, 2.6, Table 2.7, 3.4, 3.6, 4.7, 5.6, 5.13, Table 5.21, 5.13, Box 13.2, 17.2, 17.5, Table 5.23, Box 11.2, 13.2, CCP5.4} SPM.C.4.3 Maladaptation especially affects marginalised and vulnerable groups adversely (e.g., Indigenous Peoples, ethnic minorities, low-income households, informal settlements), reinforcing and entrenching existing inequities. Adaptation planning and implementation that do not consider adverse outcomes for different groups can lead to maladaptation, increasing exposure to risks, marginalising people from certain socio-economic or livelihood groups, and exacerbating inequity. Inclusive planning initiatives informed by cultural values, Indigenous knowledge, local knowledge, and scientific knowledge can help prevent maladaptation. (high confidence) (Figure SPM.4) {2.6, 3.6, 4.3, 4.6, 4.8, 5.12, 5.13, 5.14, 6.1, Box 7.1, 8.4, 11.4, 12.5, Box 13.2, 14.4, Box 14.1, 17.2, 17.5, 18.2, 17.2., CCP2.4} SPM.C.4.4 To minimize maladaptation, multi-sectoral, multi-actor and inclusive planning with flexible pathways encourages low-regret47 and timely actions that keep options open, ensure benefits in multiple sectors and systems and indicate the available solution space for adapting to long-term climate change (very high confidence). Maladaptation is also minimized by planning that accounts for the time it takes to adapt (high confidence), the uncertainty about the rate and magnitude of climate risk (medium confidence) and a wide range of potentially adverse consequences of adaptation actions (high confidence). {1.4, 3.6, 5.12, 5.13, 5.14, 11.6, 11.7, 17.3, 17.6, CCP2.3, CCP2.4, CCB SLR, CCB DEEP; CCP5.4} 47 From AR5, an option that would generate net social and/or economic benefits under current climate change and a range of future climate change scenarios, and represent one example of robust strategies.<br>APPROVED Summary for Policymakers IPCC WGII Sixth Assessment Report Subject to Copyedit SPM-29 Total pages: 35 Enabling Conditions SPM.C.5 Enabling conditions are key for implementing, accelerating and sustaining adaptation in human systems and ecosystems. These include political commitment and follow-through, institutional frameworks, policies and instruments with clear goals and priorities, enhanced knowledge on impacts and solutions, mobilization of and access to adequate financial resources, monitoring and evaluation, and inclusive governance processes. (high confidence) {1.4, 2.6, 3.6, 4.8, 6.4, 7.4, 8.5, 9.4, 10.5, 11.4, 11.7, 12.5, 13.11, 14.7, 15.6, 17.4, 18.4, CCB INDIG, CCB FINANCE, CCP2.4, CCP5.4} SPM.C.5.1 Political commitment and follow-through across all levels of government accelerate the implementation of adaptation actions (high confidence). Implementing actions can require large upfront investments of human, | Heritage | 30 - 31 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | resilient development – each involving and resulting from different societal choices influenced by different contexts and opportunities and constraints on system transitions. Climate resilient development pathways are progressively constrained by every increment of warming, in particular beyond 1.5°C, social and economic inequalities, the balance between adaptation and mitigation varying by national, regional and local circumstances and geographies, according to capabilities including resources, vulnerability, culture and values, past development choices leading to past emissions and future warming scenarios, bounding the climate resilient development pathways remaining, and the ways in which development trajectories are shaped by equity, and social and climate justice. (very high confidence) {2.6, 4.7, 4.8, 5.14, 6.4, 7.4, 8.3, 9.4, 9.3, 9.4, 9.5, 10.6, 11.8, 12.5, 13.10, 14.7, 15.3, 18.5, CCP2.3, CCP3.4, CCP4.4, CCP5.3, CCP5.4, Table CCP5.2, CCP6.3, CCP7.5, Figure TS14.d} APPROVED Summary for Policymakers IPCC WGII Sixth Assessment Report Subject to Copyedit SPM-31 Total pages: 35 SPM.D.1.2 Opportunities for climate resilient development are not equitably distributed around the world (very high confidence). Climate impacts and risks exacerbate vulnerability and social and economic inequities and consequently increase persistent and acute development challenges, especially in developing regions and sub-regions, and in particularly exposed sites, including coasts, small islands, deserts, mountains and polar regions. This in turn undermines efforts to achieve sustainable development, particularly for vulnerable and marginalized communities (very high confidence). {2.5, 4.4, 4.7, 6.3, 9.4, Box 6.4, Figure 6.5, Table 18.5, CWGB URBAN, CCB HEALTH, CCP2.2, CCP3.2, CCP3.3, CCP5.4, CCP6.2} SPM.D.1.3 Embedding effective and equitable adaptation and mitigation in development planning can reduce vulnerability, conserve and restore ecosystems, and enable climate resilient development. This is especially challenging in localities with persistent development gaps and limited resources (high confidence). Dynamic trade-offs and competing priorities exist between mitigation, adaptation, and development. Integrated and inclusive system-oriented solutions based on equity and social and climate justice reduce risks and enable climate resilient development (high confidence). {1.4, 2.6, 3.6, 4.7, 4.8, Box 4.5, Box 4.8, 5.13, 7.4, 8.5, 9.4, 10.6, Box 9.3, Box 2.2, 12.5, 12.6, 13.3, 13.4, 13.10, 13.11, 14.7, 18.4, CCB HEALTH, SRCCL, CCB DEEP, CCP2, CCP5.4} Figure SPM.5: Climate resilient development (CRD) is the process of implementing greenhouse gas mitigation and adaptation measures to support sustainable development. This figure builds on Figure SPM.9 in AR5 WGII (depicting climate resilient pathways) by describing how CRD pathways are the result of cumulative societal choices and actions within multiple arenas. Panel (a): Societal choices towards higher CRD (green cog) or lower CRD (red cog) result from interacting decisions and actions by diverse government, private sector and civil society actors, in the context of climate risks, adaptation limits and development gaps. These actors engage with adaptation, mitigation and development actions in political, economic and financial, ecological, socio-cultural, knowledge and technology, and community arenas from local to international levels. Opportunities for climate resilient development are not equitably distributed around the world. Panel (b): Cumulatively, societal choices, which are made continuously, shift global development pathways towards higher (green) or lower (red) climate resilient development. Past conditions (past emissions, climate change and APPROVED Summary for Policymakers IPCC WGII Sixth Assessment Report Subject to Copyedit SPM-32 Total pages: 35 development) have already eliminated some development pathways towards higher CRD (dashed green line). Panel (c): Higher CRD is characterised by outcomes that advance sustainable development for all. Climate resilient development is progressively harder to achieve with global warming levels beyond 1.5°C. Inadequate progress towards the Sustainable Development Goals (SDGs) by 2030 reduces climate resilient development prospects. There is a narrowing window of opportunity to shift pathways towards more climate resilient development futures as reflected by the adaptation limits and increasing climate risks, considering the remaining carbon budgets. (Figure SPM.2, Figure SPM.3) {2.6, 3.6, 7.2, 7.3, 7.4, 8.3, 8.4, 8.5, 16.4, 16.5, 17.3, 17.4, 17.5, 18.1, 18.2, 18.3, 18.4, Figure 18.1, Figure 18.2, Figure 18.3, Box 18.1, CCB | Heritage | 32 - 34 |
| IPCC | IPCC_AR6_WGII_Full_ Report | Climate resilient development in urban areas also supports adaptive capacity in more rural places through maintaining peri-urban supply chains of goods and services and financial flows (medium confidence). Coastal cities and settlements play an especially important role in advancing climate resilient development (high confidence). {6.2, 6.3, 18.3, Table 6.6, Box 9.8, CCP6.2, CCP2.1. CCP2.2, CWGB URBAN} SPM.D.3.1 Taking integrated action for climate resilience to avoid climate risk requires urgent decision making for the new built environment and retrofitting existing urban design, infrastructure and land use. Based on socioeconomic circumstances, adaptation and sustainable development actions will provide multiple benefits including for health and well-being, particularly when supported by national governments, non�governmental organisations and international agencies that work across sectors in partnerships with local communities. Equitable partnerships between local and municipal governments, the private sector, Indigenous Peoples, local communities, and civil society can, including through international cooperation, advance climate resilient development by addressing structural inequalities, insufficient financial resources, cross-city risks and the integration of Indigenous knowledge and Local knowledge. (high confidence) {6.2, 6.3, 6.4, 7.4, 8.5, 9.4, 10.5. 12.5, 17.4, 18.2, Table 6.6, Table 17.8, Box 18.1, CCP2.4, CCB GENDER, CCB INDIG, CCB FINANCE, CWGB URBAN} SPM.D.3.2 Rapid global urbanisation offers opportunities for climate resilient development in diverse contexts from rural and informal settlements to large metropolitan areas (high confidence). Dominant models of energy intensive and market-led urbanisation, insufficient and misaligned finance and a predominant focus on grey infrastructure in the absence of integration with ecological and social approaches, risks missing opportunities for adaptation and locking in maladaptation (high confidence). Poor land use planning and siloed approaches to health, ecological and social planning also exacerbates, vulnerability in already marginalised 48 Institutions: Rules, norms and conventions that guide, constrain or enable human behaviours and practices. Institutions can be formally established, for instance through laws and regulations, or informally established, for instance by traditions or customs. | Heritage | 35 - 35 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | Institutions may spur, hinder, strengthen, weaken or distort the emergence, adoption and implementation of climate action and climate governance. APPROVED Summary for Policymakers IPCC WGII Sixth Assessment Report Subject to Copyedit SPM-34 Total pages: 35 communities (medium confidence). Urban climate resilient development is observed to be more effective if it is responsive to regional and local land use development and adaptation gaps, and addresses the underlying drivers of vulnerability (high confidence). The greatest gains in well-being can be achieved by prioritizing finance to reduce climate risk for low-income and marginalized residents including people living in informal settlements (high confidence). {5.14, 6.1, 6.2, 6.3, 6.4, 6.5, 7.4, 8.5, 8.6, 9.8, 9.9, 10.4, 18.2, Table 17.8, Table 6.6, Figure 6.5, CCB HEALTH, CCP2.2, CCP5.4, CWGB URBAN} SPM.D.3.3 Urban systems are critical, interconnected sites for enabling climate resilient development, especially at the coast. Coastal cities and settlements play a key role in moving toward higher climate resilient development given firstly, almost 11% of the global population – 896 million people – lived within the Low Elevation Coastal Zone49 in 2020, potentially increasing to beyond 1 billion people by 2050, and these people, and associated development and coastal ecosystems, face escalating climate compounded risks, including sea level rise. Secondly, these coastal cities and settlements make key contributions to climate resilient development through their vital role in national economies and inland communities, global trade supply chains, cultural exchange, and centres of innovation. (high confidence) {6.2, Box 15.2, CCP2.1, CCP2.2, Table CCP2.4, CCB SLR} SPM.D.4 Safeguarding biodiversity and ecosystems is fundamental to climate resilient development, in light of the threats climate change poses to them and their roles in adaptation and mitigation (very high confidence). Recent analyses, drawing on a range of lines of evidence, suggest that maintaining the resilience of biodiversity and ecosystem services at a global scale depends on effective and equitable conservation of approximately 30% to 50% of Earth's land, freshwater and ocean areas, including currently near-natural ecosystems (high confidence). {2.4, 2.5, 2.6, 3.4, Box 3.4, 3.5, 3.6, 12.5, 13.3, 13.4, 13.5, 13.10, CCB NATURAL, CCB INDIG} SPM.D.4.1 Building the resilience of biodiversity and supporting ecosystem integrity50 can maintain benefits for people, including livelihoods, human health and well-being and the provision of food, fibre and water, as well as contributing to disaster risk reduction and climate change adaptation and mitigation.{2.2, 2.5, 2.6, Table 2.6, Table 2.7, 3.5, 3.6, 5.8, 5.13, 5.14, 12.5, Box 5.11 CCP5.4, CCB NATURAL, CCB ILLNESS, CCB COVID, CCB GENDER, CCB INDIG, CCB MIGRATE} SPM.D.4.2 Protecting and restoring ecosystems is essential for maintaining and enhancing the resilience of the biosphere (very high confidence). Degradation and loss of ecosystems is also a cause of greenhouse gas emissions and is at increasing risk of being exacerbated by climate change impacts, including droughts and wildfire (high confidence). Climate resilient development avoids adaptation and mitigation measures that damage ecosystems (high confidence). Documented examples of adverse impacts of land-based measures intended as mitigation, when poorly implemented, include afforestation of grasslands, savannas and peatlands, and risks from bioenergy crops at large scale to water supply, food security and biodiversity (high confidence). | Heritage | 35 - 36 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | well as 26 among non-governmental organisations, small and large enterprises and citizens (high confidence). At 27 the international level the Paris Agreement and the Sustainable Development Goals (SDGs), along with other 28 targets and frameworks such as the Sendai Framework for Disaster Risk Reduction, the Convention on 29 Biological Diversity (CBD) Aichi targets, the Addis Ababa Action Agenda for finance and the New Urban 30 Agenda, provide overarching goals and policy context. These agreements also provide policy goals used by 31 this IPCC Report to assess climate action across all levels of society. {1.1.2, 1.4.1, 1.4.3} 32 33 IPCC's assessments have grown and changed substantially over the last three decades. Compared to 34 earlier IPCC assessments, this report emphasizes a common risk-solution framing across all three working 35 groups. This report focuses on solutions for risk reduction and adaptation, provides more integration across 36 the natural and social sciences, applies a more comprehensive risk framework; assesses adaptation directly in 37 the context of sectoral or regional risks; engages with different forms of knowledge, including Indigenous 38 knowledge and local knowledge; and includes an increasing focus on social justice. {1.1.4, 1.4.2, Cross- 39 Chapter Box ADAPT in Chapter 1} 40 41 Adaptation plays a key role in reducing risks and vulnerability from climate change. Implementing 42 adaptation and mitigation actions together with SDGs helps to exploit synergies, reduce trade-offs and 43 makes all three more effective. From a risk perspective, limiting atmospheric greenhouse gas 44 concentrations reduces climate-related hazards while adaptation and sustainable development reduce 45 exposure and vulnerability to those hazards. Adaptation facilitates development, which is increasingly 46 hindered by impacts and risks from climate change. Development facilitates adaptation by expanding the 47 resources and capacity to reduce climate risks and vulnerability. {1.1.3, 1.5.1, 1.5.3} 48 49 The concepts of risk and risk management have become increasingly central to climate change 50 literature, research, practice and decision making (medium confidence). Risk, defined as the potential for 51 adverse consequences for human and ecological systems, recognising the diversity of values and objectives 52 associated with such systems, provides a framework for understanding the increasingly severe, 53 interconnected and often irreversible impacts of climate change; how these impacts differentially affect 54 different regions, sectors and populations; how to allocate resources best to manage the resulting risks and 55 how to evaluate the responses that reduce residual risks for current and future generations, economies and 56 ecosystems. {1.2.1, 1.3.1, 1.4.2} 57 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 1 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 1-4 Total pages: 102 1 The concepts of adaptation, vulnerability, resilience and risk provide overlapping, alternative entry 2 points for the climate change challenge (high confidence). Vulnerability is a component of risk, but also 3 an important focus independently, improving understanding of the differential impacts of climate change on 4 people of different gender, race, wealth, social status and other attributes. Vulnerability also provides an 5 important link between climate adaptation and disaster risk reduction. Resilience, which can refer to either a 6 process or outcome, encompasses not just the concept of maintaining essential function, identity and 7 structure, but also maintaining a capacity for transformation. Such transformations bring forth questions of 8 justice, power and politics. {1.2.1, 1.4.1} 9 10 Risks from climate change differ through space and time and cascade across and within regions and 11 systems. The total risk in any location may thus differ from the sum of individual risks if these 12 interactions, as well as risks from responses themselves, are not considered (high confidence). The risks 13 of climate change responses include the possibility of mitigation or adaptation responses not achieving their 14 intended objectives or having trade-offs or adverse side effects for other societal objectives. Another core 15 area of complexity in climate risk is the behaviour of systems, which includes multiple stressors unfolding 16 together, cascading or compounding interactions within and across sectors and regions and non-linear 17 responses and the potential for surprises, all of which is crucial for effective decision-making and decision- 18 support methods. The key risks assessed in this report become important in interaction with the cultures, 19 values, ethics, identities, experiences and knowledge systems of affected | Heritage | 40 - 42 |

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| IPCC | IPCC_AR6_WGII_Full_Report | groups and social movements. Many forms of adaptation 33 (depending on the type of climatic risk and societal context) are likely to be more effective, cost-efficient, 34 and potentially also more equitable when organized collectively. Stronger governance and adaptation finance 35 capabilities are usually associated with more ambitious adaptation plans and more effective implementation 36 of such plans. {1.4.2, 1.4.2} 37 38 Monitoring and Evaluation (M&E) of adaptation refers to a broad range of activities necessary for 39 tracking adaptation progress over time, improving adaptation effectiveness and successful iterative 40 risk management. Monitoring usually refers to continuous information gathering whereas evaluation 41 denotes more comprehensive assessments of effectiveness and equity, often resulting in recommendations 42 for decision makers. In some literatures M&E refers solely to efforts undertaken after implementation. In 43 other literatures, M&E refers both to efforts conducted before and after implementation. Since AR5, a 44 growing literature provides initial inventories of adaptation plans and implementation worldwide, but 45 information on effectiveness remains scare (high confidence). {1.4.3, Cross-Chapter Box ADAPT in Chapter 46 1} 47 48 The concept of limits to adaptation is dynamic in terms of the temporal, spatial and contextual 49 dimensions of climate change risks, impacts and response. Socioeconomic, technological, governance 50 and institutional systems or policies can be changed or transformed in responses to the different dimensions 51 of adaptation limits to climate change and extreme events. Adaptation limits can be soft or hard. Soft 52 adaptation limits occur when options may exist but are currently not available to avoid intolerable risks 53 through adaptive actions and hard adaptation limits occur when no adaptive actions are possible to avoid 54 intolerable risks. The level of greenhouse gas reduction, adaptation and risk management measures are the 55 key factors determining if and when adaptation limits are reached. When a limit (soft) is reached, then 56 intolerable risks and impacts may occur and additional adaptations (incremental or transformational) would 57 be required. Transformational adaptation can allow a system to extend beyond its soft limits and prevent soft ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 1 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 1-6 Total pages: 102 1 limits to become hard limits. The loss and damage associated with the future climate change impacts, beyond 2 the limits to adaptation, is an area of increasing focus, although yet to be fully developed in terms of methods 3 of assessing including non-economic values and identifying means to avoid and reduce both economic (loss 4 of asset, infrastructure, land etc.) and non-economic (loss of societal beliefs and values, cultural heritage, 5 biodiversity and ecosystem services) losses and damages. {1.4.4.1, 1.4.4.2} 6 7 Key concepts in this report provide a framework for assessing the urgency of climate change 8 adaptation. Adaptation is urgent to the extent that soft adaptation limits are currently being approached or 9 exceeded and that achieving levels of adaptation adequate to address these soft limits requires action at a 10 speed and scale faster than that represented by current trends (high confidence). In addition, adaptation is 11 urgent to the extent that any needed expansion of the future solution space requires near-term strengthening 12 and expansion of enablers such as governance, finance and information. Finally, adaptation is urgent to the 13 extent that current maladaptation and socio-economic trends, such as rapid urbanisation and continued 14 inequalities, lock in patterns of vulnerability and exposure that increase future risk (high confidence). {1.1.3, 15 1.4.4, 1.5.1} 16 17 AR6 highlights the role of transformation in meeting the Paris Agreement, the SDG and other policy 18 goals. Transformation, and the related term transition, are pluralistic concepts, embracing the idea of major, 19 fundamental changes in society or natural systems as opposed to changes that are minor, marginal, or 20 incremental. AR6 has a particular focus on transformational adaptation, which changes the fundamental 21 attributes of a socio-economic system in anticipation of climate change and its impacts. AR6 describes 22 transitions in five systems: energy, land and ecosystem, urban and infrastructure, industrial and societal. In 23 the past, transformations of such scale have been associated not only with technological and economic 24 changes, but with shifts in most aspects of society. {1.2.1.3, 1.4.4, 1.5.1} 25 26 Future transformation could be deliberate, envisioned and intended by | Heritage | 42 - 43 |
| IPCC | IPCC_AR6_WGII_Full_Report | 18 • All these trends have impacted ecosystems, food security, water resources, water quality, 19 livelihoods, health and well-being, infrastructure, transportation, tourism and recreation, as well as 20 the culture of human societies, particularly for Indigenous peoples. | Heritage | 48 - 48 |
| IPCC | IPCC_AR6_WGII_Full_Report | 31 • Coastal communities face challenging choices in crafting context-specific and integrated responses 32 to sea level rise that balance costs, benefits and trade-offs of available options and that can be 33 adjusted over time. | Heritage | 48 - 48 |
| IPCC | IPCC_AR6_WGII_Full_Report | 8 9 1.3.1.1 The Nature of Climate Risk as Assessed in this Report 10 11 Greater understanding of climate-related risks is emerging; however, there are important shortcomings for 12 the information in some regions and sectors and for developing versus developed countries. These risks 13 assume significance in interaction with the cultures, values, ethics, identities, experiences, and knowledge 14 systems of affected communities and societies, as well as their governance, finances, capabilities, and 15 resources. The key risk assessment in the IPCC AR5 informed the long-term temperature goal in the 2015 16 Paris Agreement—limiting the increase in global mean temperature to well below 2°C and pursuing efforts 17 towards limiting warming to 1.5°C (Oppenheimer et al., 2014; Pachauri et al., 2014). The IPCC Special 18 Report on Global Warming of 1.5°C, responding to an invitation by UNFCCC, used new scientific 19 information to provide a specific risk assessment associated with the ambitious warming levels targeted by 20 the Paris Agreement (Hoegh-Guldberg et al., 2019), and the Special Reports on Oceans and Land further 21 advanced the methods of transparent risk assessment (Zommers et al., 2020). The current assessment 22 expands significantly from the previous reports, aiming to inform and advance understanding of the 23 following core themes: (1) the ways changes in vulnerability and exposure modulate risks of climate change 24 impacts and risk complexity in addition to warming; (2) the knowledge basis relevant to continued 25 refinement of temperature goals; (3) the effectiveness of adaptation solutions; (4) the management of risks at 26 higher levels of warming, should ambitious climate change mitigation be unsuccessful, including limits to 27 adaptation; and (5) the benefits of climate change mitigation and emissions reductions (Section 16.1). | Heritage | 68 - 68 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 37 38 The key risk assessment conveys increasing urgency given the growing visibility of climate change impacts 39 in the current world (Sections 1.1 and 16.1). Representative key risks emerging across sectors and regions 40 include risks to coastal socio-ecological systems and terrestrial and ocean ecosystems, risks associated with 41 critical infrastructure, networks, and services; risks to living standards and human health; risks to food and 42 water security; and risks to peace and migration (Section 16.5). Compared to the AR5, the emphasis on 43 human dimensions of key climate-related risks has continued and increased, for instance the potentially 44 severe impacts for cultural heritage (IPCC, 2014c; Pachauri et al., 2014; see also Section 16.4). These human 45 dimensions are essential for understanding vulnerability, impacts, and risks central to ensuring human well- 46 being, human security, sustainable development, and poverty reduction in a changing climate. | Heritage | 68 - 68 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 41 The severity of climate change impacts will depend strongly on vulnerability, which is also dynamic and 42 includes the sensitivity and adaptive capacity of affected human and ecological systems (Ford et al., 2018; 43 Jurgilevich et al., 2017; McDowell et al., 2016; Viner et al., 2020). As a result, risks vary at fine scale across 44 communities and societies and also among people within societies, for example dependent on intersecting 45 inequalities and context-specific factors such as culture, gender, religion, ability and disability, or ethnicity 46 (Carr and Thompson, 2014; Jones and Boyd, 2011; Kuruppu, 2009; also Section 16.1.4). The dynamic social ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 1 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 1-33 Total pages: 102 1 distribution of impacts is the subject of increasing attention within climate assessment and responses), 2 including the role of adaptation, iterative risk management, and climate-resilient sustainable development 3 (Section 16.1). | Heritage | 69 - 70 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 16 17 Climate has always changed, often with severe effects on nature, including species loss 18 19 Observations provided by the historical, archaeological, and paleontological records, together with 20 paleoclimatic data, demonstrate that climatic variability has high potential to affect biodiversity and human 21 society (high confidence). The evolution of the Earth's biota has been punctuated by global biodiversity 22 crises often triggered by rapid warming (high confidence) (Benton, 2018; Figure PALEO.1; Bond and 23 Grasby, 2017; Foster et al., 2018). These so-called hyperthermal events were marked by rapid warming of 24 >1°C, which coincided with global disturbances of the carbon and water cycles, and by reduced oxygen and 25 pH in seawater (Clapham and Renne, 2019; Foster et al., 2018). Magnitudes of global temperature shifts in 26 hyperthermal events were sometimes greater than those predicted for the current century but extended over 27 longer periods of time. Rates inferred from paleo records that are coarsely resolved are inevitably lower than 28 those from direct observations during recent decades, and caution must be exercised when describing the rate 29 of recent temperature changes as unprecedented (Kemp et al., 2015). Mass extinctions, each with greater 30 than 70% marine species extinctions, occurred when the magnitude of temperature change exceeded 5.2°C 31 (Song et al., 2021), albeit species extinctions occurred at lower magnitudes of warming (medium 32 confidence). | Heritage | 77 - 77 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 7 Poleward expansions and retractions (Fordham et al., 2020; Reddin et al., 2018; Williams et al., 2018) as 8 well as migration upslope and downslope in response to warming and cooling were common adaptations 9 (Iglesias et al., 2018; Ortega-Rosas et al., 2008). During warming periods, diversity loss was common near 10 the equator (medium confidence)(Kiessling et al., 2012; Kröger, 2017; Yasuhara et al., 2020) while diversity 11 gains and forest expansion occurred in high latitudes (Brovkin et al., 2021). Comparison of contemporary 12 shells and skeletons with historical collections in museums (Barnes et al., 2011) and the analysis of skeletons 13 of long-lived organisms (Cantin et al., 2010) indicate significant climate-induced change in organismic 14 growth rates today (high agreement, medium confidence). | Heritage | 78 - 78 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 52 53 Climate change destroys unique natural archives and important cultural heritage sites 54 55 Climate change not only impacts past ecosystems and societies but also the remains they have left. The 56 progressive loss of archaeological and historical sites and natural archives of paleo environmental data WGI 57 Chapter 2 constitutes often-overlooked impacts of climate change (Anderson et al., 2017; Climate Change ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 1 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 1-42 Total pages: 102 1 Cultural Heritage Working Group International, 2019; Cross-Chapter Box SLR in Chapter 3; Hollesen et al., 2 2018). These archives include peat bogs and coastal archives lost to sea-level rise, droughts and fires, 3 degradation through permafrost thaw, and dissolution. The ancient cultural diversity documented by such 4 sites is an important resource for future adaptation (Burke et al., 2021; Rockman and Hritz, 2020). Since 5 many of these sites constitute anchors for indigenous knowledge, their loss is not just data lost to science; it 6 also interrupts intergenerational transmission of knowledge (Green et al., 2009). | Heritage | 78 - 79 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 31 32 Such experience-based and practical knowledge is obtained over generations through observing and working 33 directly within various environments. Knowledge may be place-based and rooted in local cultures, especially 34 when it reflects the beliefs of long-settled communities who have strong ties to their natural environments 35 (Orlove et al., 2010). Other times, knowledge may be embedded in institutions or oral traditions that 36 mobilise them across contexts, for example, as migrant populations bring their knowledge across different 37 regions, and have global relevance. Scientific insights often confirm findings from both IK and LK 38 (Ignatowski and Rosales, 2013), but IK and LK also provide specific, alternative ways to understand 39 environmental change including tacit and embodied aspects of knowledge (Mellegård and Boonstra, 2020), 40 that may be crucial to foster local action and which are not easily captured in scientific knowledge (including 41 cultural indicators, scales and interconnectedness between ecosystems). Multiple knowledge systems (i.e. | Heritage | 81 - 81 |

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| IPCC | IPCC_AR6_WGII_Full_Report | 20 21 The AR4 was the first IPCC report to explicitly discuss the value of IK and LK in adaptation and mitigation 22 processes. AR5 recognized the importance of creating synergies across disciplines in the production of 23 knowledge, acknowledging the importance of 'non-scientific sources such as Indigenous knowledge, which 24 may not follow discipline conventions but nevertheless reflects the outcomes of learning across generations 25 (Burkett et al., 2014) and explains the importance of including local and Indigenous knowledge and diverse 26 stakeholder interests, values, and in local decision-making processes (Jones et al., 2014). Such processes 27 should not only be done in partnership with IK and LK knowledge holders but, when possible, led by them 28 (Inuit Tapiriit Kanatami, 2018). Recent IPCC reports have included distinct sections dedicated to IK and LK 29 (e.g., SROCC, IPCC, 2019b). The IPCC Special Report on Climate Change and Land (SRCCL) includes a 30 section on "Local and Indigenous knowledge for addressing land degradation" (2019a) and the IPCC Special 31 Report on Ocean and Cryosphere (SROCC) describes local knowledge as 'what non-Indigenous 32 communities, both rural and urban, use on a daily and lifelong basis,' a type of knowledge which is 33 recognized as 'multi-generational, embedded in community practices and cultures, and adaptive to changing 34 conditions' (2019b). The IPCC Special Report on Global Warming of 1.5°C emphasized the high 35 vulnerability of Indigenous Peoples to climate change, and stated that disadvantaged and vulnerable 36 populations including Indigenous Peoples and certain local communities are at disproportionately higher risk 37 of suffering adverse consequences with global warming of 1.5°C and beyond (IPCC, 2018b). The report also 38 assessed evidence in relation to the importance of including IK and LK in adaptation options, explaining 39 their role in early warning systems and arguing that they are part of a range of approaches to catalyse wide- 40 scale values and consistent with adapting to and limiting global warming to 1.5°C (IPCC, 2018b). | Heritage | 82 - 82 |
| IPCC | IPCC_AR6_WGII_Full_Report | 24 25 Since principles of justice are substantive normative commitments that have been debated for centuries, it 26 would be unrealistic to expect a universal consensus. Nevertheless, there is broad agreement about the core 27 issues. Just normative principles are ones that result in fair and equitable allocation of goods, vulnerabilities 28 and risks (Caney, 2014; Jafry et al., 2018; Schlosberg, 2009; Schlosberg, 2013) 29 30 It is common to distinguish between distributive justice, procedural justice and recognition (Forsyth, 2018; 31 Fraser, 1999; Olazabal et al., 2021; Reckien et al., 2017; Schlosberg, 2003; Schlosberg, 2009). The first 32 refers to the distribution of burdens and benefits; the second to who decides and participates in decision- 33 making; while recognition entails basic respect and robust engagement with and fair consideration of diverse 34 values, cultures, perspectives, and worldviews. Recognition is closely to distributive and procedural justice 35 (Hourdequin, 2016). Without recognition, actors may not benefit from the two other aspects of justice 36 (medium confidence). Recognition thus represents both a normative principle as well as an underlying cause 37 of unjust distribution and lack of democratic participation (Svarstad and Benjaminsen, 2020). However, 38 recognition is still under-represented in climate justice compared to general scholarship and debate on justice 39 principles (Benjaminsen et al., 2021; Chu and Michael, 2018). | Heritage | 87 - 87 |
| IPCC | IPCC_AR6_WGII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 1 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 1-62 Total pages: 102 1 2 Fundamental questions about equity and justice in adaptation include gender and intersectionality (see Cross- 3 Chapter Box GENDER in Chapter 18, Section 1.4.1.1 Chapter 18;) and broader critiques of who participates 4 in processes of adaptation planning and implementation, who receives investments, who and what benefits 5 from them, who makes key decisions regarding adjustments through time (Boeckmann and Zeeb, 2016; 6 Byskov et al., 2021; Eriksen et al., 2021; Nightingale et al., 2019; Pelling and Garschagen, 2019; Taylor et 7 al., 2014), and how climate justice intersects with other justice agendas. Attention is also turning to relations 8 and tensions between different adaptation approaches, scales, constraints, limits, losses, enablers and 9 outcomes (Barnett et al., 2015; Crichton and Esteban, 2017; Deshpande et al., 2018; Gharbaoui and Blocher, 10 2017; McNamara and Jackson, 2019; Mechler and Schinko, 2016; Pelling et al., 2015). Evident here is an 11 ongoing, serious knowledge gap around the long-term repercussions of adaptation interventions. There is 12 growing awareness of the need to address the potential for maladaptation (Sections 1.4.2.4; 5.13.3; 15.5.1, 13 17.5.2, Chapter 4 on Water). Concerns about maladaptation have led to renewed calls to open the "black 14 box" of decision making to examine the influence of power relationships, politics and institutional 15 culture(Biesbroek et al., 2013; Eriksen et al., 2015; Goldman et al., 2018), including the power-adaptation 16 linkage itself (Woroniecki et al., 2019), external factors outside the decision-making process (Eisenack et al., 17 2014) and the influence of leadership on adaptation processes and outcomes (Meijerink et al., 2014; Vignola 18 et al., 2017). | Heritage | 98 - 99 |
| IPCC | IPCC_AR6_WGII_Full_Report | 25 26 [END CROSS CHAPTER BOX ADAPT HERE] 27 28 29 1.4.4 Limits to Adaptation 30 31 The effectiveness of adaptation efforts also depends on the constraints and limits that human and natural 32 systems face when confronted with increasingly higher levels of climate risks. The concept of adaptation 33 limits strongly affects any appropriate balance among adaptation and mitigation actions in the sense that less 34 mitigation makes adaptation harder or even infeasible. Adaptation limits refer to the point at which an 35 actor's objectives (or system needs) cannot be secured from intolerable risks through adaptive actions (WGII 36 AR6 Glossary). Adaptation limits can be soft or hard. Soft adaptation limits occur when options may exist 37 but are currently not available to avoid intolerable risks through adaptive actions and hard adaptation limits 38 occur when no adaptive actions are possible to avoid intolerable risks. Intolerable risks are those which 39 fundamentally threaten a private or social norm — threatening, for instance, public safety, continuity of 40 traditions, a legal standard or a social contract -- despite adaptive action having been taken (Dow et. al. | Heritage | 99 - 99 |
| IPCC | IPCC_AR6_WGII_Full_Report | 5 Adaptation limits depend on a complex function of interactions between social, ecological, technological and 6 climatic elements, which appear to have thresholds beyond which adaptation can be infeasible and represent 7 limits to adaptation. Such thresholds are endogenous to society and hence contingent on ethics, knowledge, 8 attitudes, culture, governance, institutions and policies (Abrahamson et al., 2009; Tschakert et al., 2017). | Heritage | 100 - 100 |

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| IPCC | IPCC_AR6_WGII_Full_Report | 27 28 For assessing the projected losses and damages, residual risks also need to be taken into account. The loss 29 and damage associated with the future climate change impacts, beyond the limits to adaptation, is an area of 30 increasing focus, although yet to be fully developed in terms of methods of assessing including non- 31 economic losses and damages as well as identifying means to avoid and reduce both economic (loss of asset, 32 infrastructure, land etc.) and non-economic (loss of societal beliefs and values, cultural heritage, biodiversity 33 and ecosystem services) losses and damages (Andrei et al., 2015; Fankhauser and Dietz, 2014). There is an 34 increasing evidence in economic and non-economic losses due to climate extremes and slow onset events 35 under observed increases in global temperatures (Coronese et al., 2019; Section 8.3.4; Grinsted et al., 2019; 36 Kahn et al., 2019), however assessing non-economic losses and damages is lacking and needs more attention 37 (Serdeczny et al., 2016; Tschakert et al., 2019). The aggregate losses and damages would be higher if non- 38 economic values are considered in such assessment (Laurila-Pant et al., 2015; McShane, 2017). Solutions to 39 reduce or avoid loss and damage need a robust conceptual framework and analysis, focusing the future losses 40 rather than past losses (Preston, 2017) and emphasis on avoiding versus addressing loss and damage, and the 41 role of justice (Boyd et al., 2017), clarity on the detection and attribution (Section 8.2.1, Section 8.3.3), 42 effectiveness of risk management and adaptation (Cross-Chapter Box FEASIB in Chapter 18, Section 1.4), 43 the concepts of risk transfer, liability and financing (Cross-Chapter Box FINANCE in Chapter 17, Section 44 17.4.2), and the role of transformation (Section 1.5). | Heritage | 101 - 101 |
| IPCC | IPCC_AR6_WGII_Full_Report | 54 The 1.5 Special Report suggests that transformation is needed to generate the four system transitions. In 55 many literatures, transformation is considered a more expansive process than transition, with the former less 56 exclusively focused on socio-technical systems and more engaged with questions of power, politics, 57 capabilities, culture, identity and sense-making (Gillard et al., 2016; Hölscher et al., 2018; Linnér and ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 1 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 1-66 Total pages: 102 1 Wibeck, 2019). This report generally takes this more expansive view of transformation, often to engage with 2 issues of equity, climate justice and large-scale institutional and societal change (Box 18.3). | Heritage | 102 - 103 |
| IPCC | IPCC_AR6_WGII_Full_Report | 19 20 Various literatures describe multiple, co-evolving societal elements which organize themselves into stable 21 regimes that, under some circumstance, can undergo significant change. The sustainability transitions 22 literature provides one central focus for understanding such processes and potential intervention points for 23 actors seeking change (Köhler et al., 2019). This literature identifies three, interacting scales: the micro, 24 meso and macro.(Geels, 2004; Köhler et al., 2019) The micro level reflects changing individual choices, 25 attitudes and motivations. The meso reflects socio-technical systems, 'a cluster of elements, including 26 technology, regulations, user practices and markets, cultural meanings, infrastructure, maintenance networks 27 and supply networks' The macro reflects the cultures, institutions, norms, governance and other broad 28 organising features of society. The sustainability transitions literature generally focuses on change that 29 originates and occurs within the meso scale, while the transformation literature focuses on change within and 30 among all scales. This Working Group II report often considers three interacting scales labelled personal, 31 practical and political (O'Brien and Sygna, 2013). Working Group III often employs the multi-level 32 perspectives framework (Geels, 2004) and the more actor-oriented three domains of decision-making 33 framework (Grubb et al., 2014; WGIII Section 1.6.4) to describe related societal scales. | Heritage | 105 - 105 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | ecosystems contain stocks of ~3500 GtC in vegetation, permafrost, and soils, three to five times the amount 36 of carbon in unextracted fossil fuels (high confidence), and >4 times the carbon currently in the atmosphere 37 (high confidence). Tropical forests and Arctic permafrost contain the highest ecosystem carbon, with 38 peatlands following (high confidence). Deforestation, draining and burning of peatlands, and thawing of 39 Arctic permafrost due to climate change shifts these ecosystems from carbon-sinks to carbon-sources (high 40 confidence). {2.4.3.6; 2.4.3.8; 2.4.3.9. 2.4.4.4} 41 42 Evidence indicates that climate change is affecting many species, ecosystems, and ecological processes 43 that provide ecosystem services connected to human health, livelihoods, and well-being (medium 44 confidence). These services include climate regulation, water and food provisioning, pollination of crops, 45 tourism and recreation. It is difficult establish end-to-end attribution from climatic changes to changes in a 46 given ecosystem service and to identify the location and timing of impacts. This limits specific adaptation 47 planning, but protection and restoration of ecosystems could build resilience of service provision.{2.2; 2.3; 48 2.4.2.7; 2.4.5; 2.6.3; 2.6.4; 2.6.5; 2.6.6; 2.6.7; Cross-Chapter Box NATURAL this Chapter; Cross-Chapter 49 Box ILLNESS this Chapter; Cross-Chapter Box EXTREMES this Chapter; Cross-Chapter Box COVID in 50 Chapter 7; Cross-Chapter Box MOVING PLATE in Chapter 5} 51 52 Projected Risks 53 54 Climate change increases risks to fundamental aspects of terrestrial and freshwater ecosystems, with 55 the potential for species' extinctions to reach 60% at 5°C GSAT warming (high confidence), biome 56 shifts (changes in the major vegetation form of an ecosystem) on 15% (at 2ºC warming) to 35% (at 57 4ºC warming) of global land (medium confidence), and increases in the area burned by wildfire of 35% ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 2 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 2-6 Total pages: 237 1 (at 2ºC warming) to 40% (at 4ºC warming) of global land (medium confidence). {2.5.1; 2.5.2; 2.5.3; 2 2.5.4; Figure 2.6; Figure 2.7; Figure 2.8; Figure 2.9; Figure 2.11; Table 2.5; Table 2.S.2; Table 2.S.4; Cross- 3 Chapter Box DEEP in Chapter 1; Cross-Chapter Paper 1} 4 5 Extinction of species is an irreversible impact of climate change, the risk of which increases steeply 6 with rises in global temperature. It is likely that the percentage of species at high risk of extinction (median 7 and maximum estimates) will be 9% (max 14%) at 1.5°C, 10% (max 18%) at 2°C, 12% (max 29%) at 3.0°C, 8 13% (max 39%) at 4°C and 15% (max 48%) at 5°C (Figure 2.7). Among groups containing largest numbers 9 of species at high risk of extinctions for mid-levels of warming (3.2°C) are: invertebrates (15%), specifically 10 pollinators (12%), amphibians (11%, but salamanders are at 24%) and flowering plants (10%). All groups 11 fare substantially better at 2°C, with extinction projections reducing to <3% for all groups, except 12 salamanders at 7% (medium confidence) (Figure 2.8a). Even the lowest estimates of species' extinctions 13 (9%) are 1000x natural background rates. Projected species' extinctions at future global warming levels are 14 consistent with projections from AR4, but assessed on many more species with much greater geographic 15 coverage and a broader range of climate models. {2.5.1.3; Figure 2.6; Figure 2.7; Figure 2.8; Cross-Chapter 16 Box DEEP in Chapter1; Cross-Chapter Paper 1} 17 18 Species are the fundamental unit of ecosystems, and increasing risk to species increases risk to 19 ecosystem integrity, functioning and resilience with increasing warming (high confidence). As species 20 become rare, their roles in the functioning of the ecosystem diminishes (high confidence). Loss of species 21 reduces the ability of an ecosystem to provide services and lowers its resilience to climate change (high 22 confidence). At 1.58°C (median estimate), >10% of species are projected to become endangered (sensu 23 IUCN); at 2.07°C (median) >20% of species are projected to become endangered, representing high and very 24 high biodiversity risk, respectively (medium confidence){2.5.4; Figure 2.8b, Figure 2.11; Table 2.5, Table 25 2.S.4}. Biodiversity loss is projected for more regions with increasing warming, and to be worst in northern 26 South America, southern Africa, most of Australia, and northern high latitudes (medium confidence){2.5.1.3; 27 Figure 2.6}. | Heritage | 144 - 145 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 14 15 There is new evidence that species can persist in refugia where conditions are locally cooler, when they 16 are declining elsewhere (high confidence) {2.6.2}. Protecting refugia, for example where soils remain wet 17 during drought or fire risk is reduced, and in some cases creating cooler microclimates, are promising 18 adaptation measures {2.6.3; 2.6.5; CCP1; CCP5.2.1}. There is also new evidence that species can persist 19 locally because of plasticity, including changes in phenology or behavioural changes that move an individual 20 into cooler micro-climates, and genetic adaptation may allow species to persist for longer than might be 21 expected from local climatic changes (high confidence) {2.4.2.6; 2.4.2.8, 2.6.1}. There is no evidence to 22 indicate that these mechanisms will prevent global extinctions of rare, very localised species at their climatic 23 limits or species inhabiting climate/habitat zones that are disappearing (high confidence). {2.4.2.8, 2.5.1, 24 2.5.3.1, 2.5.4, 2.6.1, 2.6.2, 2.6.5} 25 26 Since AR5, many adaptation plans and strategies have been developed to protect ecosystems and 27 biodiversity but there is limited evidence of the extent to which adaptation is taking place and virtually 28 no evaluation of the effectiveness of adaptation measures in the scientific literature (medium 29 confidence). This is an important evidence gap that needs to be addressed to ensure a baseline is available 30 against which to judge effectiveness and develop and refine adaptation in future. Many proposed adaptation 31 measures have not been implemented (low confidence) {2.6.2; 2.6.3; 2.6.4; 2.6.5; 2.6.6; 2.6.8; 2.7} 32 33 Ecosystem restoration and resilience building cannot prevent all impacts of climate change, and 34 adaptation planning needs to manage inevitable changes to species distributions, ecosystem structure 35 and processes (very high confidence). Actions to manage inevitable change include local modification of 36 microclimate or hydrology, adjustment of site management plans and facilitating the dispersal of vulnerable 37 species to new locations, both by increasing habitat connectivity or by active translocations of species. | Heritage | 146 - 146 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 43 44 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 2 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 2-15 Total pages: 237 1 2 Figure 2.1: Map of global land use change from 1982-2016. Based on satellite records of global tree canopy (TC), 3 short vegetation (SV) and bare ground (BG) cover (from Song et al., 2018). a) Mean annual estimates of cover (% of 4 pixel area at 0.05° resolution). b) Long-term change estimates (% of pixel area at 1.5° resolution), with pixels showing 5 a statistically significant trend (n = 35 years, two-sided Mann–Kendall test, P < 0.05) in TC, SV or BG. The dominant 6 changes are Tree canopy gain with Short vegetation loss; Bare Ground gain with Short vegetation loss; Tree canopy 7 gain with Bare Ground loss; Bare Ground gain with Tree canopy loss; 5, Short vegetation gain with Bare Ground loss; 8 and Short vegetation gain with TC loss. Grey indicates areas with no significant change between 1982-2016. | Heritage | 153 - 154 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 31 32 Introduction 33 34 Extreme events are now causing profound negative effects across all realms of the world (marine, terrestrial, 35 freshwater and polar) (medium confidence) (WGI, Chapter 9, 11; WGII AR6 Section 2.3.1, 2.3.2, 2.3.3.5, 36 Chapter 3, Chapters 9–12). Changes to population abundance, species distributions, local extirpations and 37 extinctions are leading to long-term, potentially irreversible shifts in the composition, structure and function 38 of natural systems (medium confidence) (Frolicher and Laufkotter, 2018; Harris et al., 2018a; Maxwell et al., 39 2019; Smale et al., 2019). These effects have widespread ramifications for ecosystems and the services they 40 provide – physical habitat, erosion control, carbon storage, nutrient cycling and water quality, with knock-on 41 effects on tourism, fisheries, forestry and other natural resources (Kaushal et al., 2018; Heinze et al., 2021; 42 Pörtner et al., 2021). | Heritage | 161 - 161 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 34 35 During their range shifts, forest pests remain climate-sensitive. For example, the distribution of Western 36 Spruce Budworm is limited at its warm range edges by adverse effects of mild winters on overwinter 37 survival, and at its cool range limits by ability to arrive at a cold-resistant stage before winter arrives 38 (Régnière and Nealis, 2019). We might therefore expect tree mortality from insect outbreaks to be most 39 severe in sites climatically less suitable for the plants, where plants would be under more stress. However, 40 (Jaime et al., 2019), using separate SDMs (MaxEnt) for the insects and plants, found that mortality of Scots 41 Pine from bark beetles was highest in sites most climatically suitable for the trees as well as for the insects. | Heritage | 166 - 166 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 44 45 Range shifts in a poleward and upward direction, following expected trajectories given the local and regional 46 climate trends, are strongly occurring in freshwater fish populations in North America (Lynch et al., 2016b), 47 Europe (Comte and Grenouillet, 2013; Gozlan et al., 2019) and Central Asia (Gozlan et al., 2019). Cold 48 water fish, such as coregonids and smelt have been negatively affected at the equatorial borders of their 49 distributions (Jeppesen et al., 2012). Upward elevational range shifts in rivers and streams have been 50 observed. Systematic shifts towards higher elevation and upstream were found for 32 stream fish species in 51 France following regional variation in climate change (Comte and Grenouillet, 2013). Bull trout (Salvelinus confluentus) in Idaho (USA), were estimated to have lost 11–20% (8–16% decade-1 52 ) of the headwater stream 53 lengths necessary for cold water spawning and early juvenile rearing, with the largest losses occurring in the 54 coldest habitats (Isaak et al., 2010). Range contractions of the same species have been found in the Rocky 55 Mountain watershed (Eby et al., 2014). Likewise, the distribution of the stonefly Zapada glacier, endemic to 56 alpine streams of Glacier National Park in Montana (USA), has been reduced over several decades by ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 2 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 2-28 Total pages: 237 1 upstream retreat to higher, cooler sites as water temperatures have increased and glacial masses decreased 2 (Giersch et al., 2015). | Heritage | 166 - 167 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 14 15 2.4.2.2 Observed Local Population and Global Species' Extinctions Driven by Climate Change 16 17 Disappearances of local populations within a species range are more frequent and better documented than 18 whole species' extinctions, and attribution to climate change is possible for sites with minimal confounding 19 non-climatic stressors. Changes of temperature extremes are often more important to these local extinction 20 rates than changes of mean annual temperature (see Sections 2.3.1, 2.3.2, 2.3.3.5, 2.4.2.6, Cross-chapter Box 21 EXTREMES this Chapter; Parmesan et al., 2013). In a study of 538 plant and animal species, sites with local 22 extinctions were associated with smaller changes of mean annual temperature but larger and faster changes 23 of hottest yearly temperatures than sites where populations persisted (Román-Palacios and Wiens, 2020). | Heritage | 167 - 167 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 24 Near warm range limits, 44% of species had suffered local extinctions. In both temperate and tropical 25 regions, sites with local extinction had greater increases in maximum temperatures than those without (Tmax 26 increased 0.456°C and 0.316°C vs. Tmean increase of 0.153 °C and 0.061 °C for temperate (n=505 sites) and 27 tropical (n=76 sites), respectively, P < 0.001) (Román-Palacios and Wiens, 2020). | Heritage | 167 - 167 |

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| IPCC | IPCC_AR6_WGII_Full_Report | 28 29 Wiens (2016) assumed that population extinctions were primarily driven by climate change when they 30 occurred at elevational or latitudinal "warm edge" range limits, and were in relatively undisturbed sites that 31 were stated by authors to be under increasing climatic stress. By this criterion, climate-caused local 32 extinctions were widespread among plants and animals, detected in 47% of 976 species examined. The 33 percentage of species suffering these extinctions was higher in the tropics (55%), than in temperate habitats 34 (39%), higher in freshwater (74%), than in marine (51%) or terrestrial (46%) habitats and higher in animals 35 (50%) than in plants (39%). The difference between plants and animals varied with latitude: in the temperate 36 zone a much higher proportion of animals than plants suffered range-limit extinctions (38.6% of 207 animal 37 species versus 8.6% of 105 plants, $p < 0.0001$) while at tropical sites local extinction rates were 38 (nonsignificantly) higher in plants (59% of 155 species) than in animals (52% of 349 species), the reverse of 39 their temperate zone relationship. Rates varied among animal groups, from 35% in mammals through 43% in 40 birds to 56% in insects and 59% in fish (Wiens, 2016). | Heritage | 167 - 167 |
| IPCC | IPCC_AR6_WGII_Full_Report | 3 4 Two terrestrial and freshwater species have gone extinct, with climate change implicated as a key driver. The 5 cloud-forest-restricted Golden toad (Incilius periglenes) was extinct by 1990 in a nature preserve in Costa 6 Rica, driven by successive extreme droughts. This occurred in the absence of chytridiomycosis infection, 7 caused by the fungal pathogen Batrachochytrium dendrobatidis (BD), verified during field censuses of 8 golden toad populations in the process of extinction and through genetic analyses of museum specimens, 9 although Bd was present in other frog species in the region (medium evidence, high agreement) (Pounds et 10 al., 1999; Pounds et al., 2006; Puschendorf et al., 2006; Richards-Hrdlicka, 2013). The interaction between 11 expansion of chytrid fungus globally and local climate change is implicated in the extinction of a wide range 12 of tropical amphibians (see Section 2.4.2.7.1 Case study 2 Chytrid fungus and climate change). | Heritage | 168 - 168 |
| IPCC | IPCC_AR6_WGII_Full_Report | 45 46 Behavioural plasticity such as nest-site selection can provide a partial buffer from the effects of increasing 47 temperature, but there are environmental and physical limits to this plasticity (medium confidence) 48 (Refsnider and Janzen, 2016; Telemeco et al., 2017). Plasticity in heat tolerance (e.g. due to reversible 49 acclimation or acclimatisation) can also potentially compensate for rising temperatures (Angilletta Jr, 2009), 50 but ectotherms have relatively low acclimation in thermal tolerance and acclimation is expected to only 51 slightly reduce overheating risk in even the most plastic taxa (low confidence) (Gunderson and Stillman, 52 2015). | Heritage | 173 - 173 |
| IPCC | IPCC_AR6_WGII_Full_Report | 27 28 Warmer temperatures have increased blood-feeding insect harassment of reindeer with compounding 29 consequences: (1) increased insect bite rates lead to higher parasite loads, (2) time spent by raindeer in trying 30 to escape biting flies reduces foraging while simulataneously increasing energy expenditure, (3) the 31 combination of (1) and (2) lead to poor body condition, that subsequently leads to (4) reduced winter 32 survival and fecundity (Mallory and Boyce, 2017). As temperatures warm and connectivity increases 33 between the Arctic and the rest of the world, tourism, resource extraction, and increased commercial 34 transport will create additional risks of biological invasion by infectious agents and their hosts (Pauchard et 35 al., 2016). These increases in introduction risk compounded with climate change have already begun to harm 36 indigenous peoples dependent on hunting and herding livestock (horses and reindeer) that are suffering 37 increased pathogen infection (Deksne et al., 2020; Stammler and Ivanova, 2020). | Heritage | 178 - 178 |
| IPCC | IPCC_AR6_WGII_Full_Report | 38 39 2.4.2.7.3 Biodiversity-disease links 40 Anthropogenic impacts, such as disturbances caused by climate change, can reduce biodiversity through 41 multiple mechanisms and increase disease risk to humans (limited evidence, low agreement) but more 42 research is needed to understand the underlying mechanisms (Civitello et al., 2015; Young et al., 2017b; 43 Halliday et al., 2020; Rohr et al., 2020; Glidden et al., 2021). Known wildlife hosts of human-shared 44 pathogens and parasites overall comprise a greater proportion of local species richness (18–72% higher) and 45 abundance (21–144% higher) in sites under substantial human use (agricultural and urban lands) compared 46 with nearby undisturbed habitats (Gibb et al., 2020). | Heritage | 178 - 178 |
| IPCC | IPCC_AR6_WGII_Full_Report | 3 4 In the absence of evolutionary constraints, climate debts can be cancelled by genetically-based increases in 5 thermal tolerance and ability to perform in high ambient temperatures. In species already showing local 6 adaptation to climate, populations currently living at relatively cool sites should be able to evolve to adopt 7 traits of populations currently at warmer sites, as their local experience of climate changes (Singer, 2017; 8 Socolar et al., 2017). | Heritage | 182 - 182 |
| IPCC | IPCC_AR6_WGII_Full_Report | 43 44 2.4.3.2 Global Patterns of Observed Biome Shifts Driven by Climate Change 45 46 2.4.3.2.1 Observed biome shifts predominantly driven by climate change 47 Th IPCC Fifth Assessment Report and a meta-analysis found that vegetation at the biome level shifted 48 poleward latitudinally and upward altitudinally due to anthropogenic climate change at 19 sites in boreal, 49 temperate, and tropical ecosystems from 1700 to 2007 (Gonzalez et al., 2010a; Settele et al., 2014). In these 50 areas, temperature increased 0.4° to 1.6ºC above the pre-industrial period (Gonzalez et al., 2010a; Settele et 51 al., 2014). Field research since the IPCC Fifth Assessment Report detected additional poleward and upslope 52 biome shifts over periods of 24 to 210 years at numerous sites (described below) but were not directly 53 attributed to anthropogenic climate change as the studies were not designed nor conducted properly for 54 attribution. | Heritage | 183 - 183 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 6 7 Other biome shifts consistent with climate change and not substantially affected by local land use include 8 northward shifts of deciduous forest into boreal conifer forest in Canada (5 km between 1970-2012, (Sittaro 9 et al., 2017) and 20 km between 1970-2014, (Boisvert-Marsh et al., 2019)) and northward shifts of 10 temperate conifer into boreal conifer forest in Canada (21 km between 1970-2015, (Boisvert-Marsh and de 11 Blois, 2021)). Research detected upslope shifts of boreal and sub-alpine conifer forest into alpine grassland 12 at 143 sites on four continents (41 m, 1901-2018, (Lu et al., 2021)) and individual sites in Canada (54 m, 13 1900-2010, (Davis et al., 2020)), China (300 m, 1910-2000 (Liang et al., 2016); 33 m, 1985-2014, (Du et 14 al., 2018)), Nepal (50 m, 1860-2000, (Sigdel et al., 2018)), Russia (150 m, 1954-2006, (Gatti et al., 2019)) 15 and the United States (19 m, 1950-2016, (Smithers et al., 2018); 38 m, 1953-2015, (Terskaia et al., 2020)). | Heritage | 184 - 184 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 19 20 In summary, anthropogenic climate change has caused latitudinal and elevational biome shifts in at least 19 21 sites in boreal, temperate, and tropical ecosystems between 1700 and 2007, where temperature increased 0.4° 22 to 1.6ºC above the pre-industrial period (robust evidence, high agreement). Additional cases of 5 to 20 km 23 northward and 20 to 300 m upslope biome shifts between 1860 and 2016, under approximately 0.9ºC mean 24 global temperature increase above the pre-industrial period, are consistent with climate change (medium 25 evidence, high agreement). | Heritage | 184 - 184 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 35 36 Upslope and poleward forest shifts have occurred where timber harvesting or livestock grazing was 37 abandoned, allowing regeneration of trees at sites in Canada (Brice et al., 2019; Wang et al., 2020b), France 38 (Feuillet et al., 2020), Italy (Vitali et al., 2017), Spain (Ameztegui et al., 2016), the United States (Wang et 39 al., 2020b) and mountain areas across Europe (Cudlin et al., 2017). Intentional use of fire drove an upslope 40 forest shift in Peru (Bush et al., 2015) while mainly human-ignited fires drove conversion of shrubland to 41 grassland in a drought-affected area of the United States (Syphard et al., 2019b). In eastern Canada, timber 42 harvesting and wildfire drove conversion of mixed conifer-broadleaf forests to broadleaf-dominated forests 43 (Brice et al., 2020; Wang et al., 2020b). | Heritage | 184 - 184 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 44 45 Shrub encroachment onto savanna has occurred at numerous sites, particularly across the Southern 46 Hemisphere, mainly between 1992 and 2010 (Criado et al., 2020). Globally, overgrazing initiates shrub 47 encroachment by reducing grasses more than woody plants, while fire exclusion maintains the shrub cover 48 (D'Odorico et al., 2012; Caracciolo et al., 2016; Bestelmeyer et al., 2018). The magnitude of woody cover 49 change in savannas is not correlated to mean annual temperature change (Criado et al., 2020), however, 50 higher atmospheric CO2 increases shrub growth in savannas (Nackley et al., 2018; Manea and Leishman, 51 2019). A global remote sensing analysis of biome changes from all causes, including agricultural and grazing 52 expansion and deforestation, estimated that 14% of pixels changed between 1981 and 2012, although this 53 approach can overestimate global changes since it uses a new biome classification system, which doubles the 54 conventional biome classifications (Higgins et al., 2016). In addition to climate change, land use change 55 causes vegetation changes at the biome level (robust evidence, high agreement). | Heritage | 184 - 184 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 13 14 The global extent of grasslands is declining significantly because of climate change (medium confidence). In 15 temperate and boreal zones, where about half of treelines are shifting, they are overwhelmingly expanding 16 poleward and upward, with accompanying loss of montane grassland (robust evidence, high agreement); 17 whereas tropical treelines have been generally stable (medium evidence, medium agreement) (Harsch et al., 18 2009; Rehm & Feeley 2015; Silva et al., 2016; Andela et al., 2017; Song et al., 2018; Aide et al., 2019; 19 Gibson and Newman, 2019). The Eurasian steppes experienced a 1% increase in woody cover per decade 20 since 2000 (Liu et al., 2021) and Inner Mongolian grasslands in China experienced broad encroachment as 21 well (Chen et al., 2015). Climatic drivers of woody expansion in temperature limited grasslands, particularly 22 alpine grasslands, are most frequently attributed to warming (robust evidence, high agreement, high 23 confidence) (D'Odorico et al., 2012; Hagedorn et al., 2014), increases in water and nutrient availability from 24 thawing permafrost (medium evidence, high agreement) (Zhou et al., 2015b; Silva et al., 2016) and rising 25 CO2 (medium evidence, medium agreement) (Frank et al., 2015; Aide et al., 2019). Interactions between land 26 use changes: land abandonment, grazing management shifts, and fire suppression, and climate change are 27 contributing factors (Liu et al., 2021) 28 29 Remote sensing shows overall increasing trends in both the annual maximum NDVI and annual mean NDVI 30 in global grasslands ecosystems between 1982 and 2011 (Gao et al., 2016). Multiple lines of evidence 31 indicate that changes in grassland productivity are positively correlated with increases in mean annual 32 precipitation (Hoover et al., 2014; Brookshire and Weaver, 2015; Gang et al., 2015; Gao et al., 2016; Wilcox 33 et al., 2017; Wan et al., 2018). Increasing temperatures positively impact grassland production and biomass, 34 especially in temperature limited regions (Piao et al., 2014; Gao et al., 2016). However, grasslands in hot 35 areas are expected to decrease production with increases in temperature (limited evidence, low agreement) 36 (Gang et al., 2015). Nevertheless, grassland responses to warming and drought are being ameliorated by 37 increasing CO2 and associated improved water use efficiency (Roy et al., 2016). For example, in a cool 38 temperate grassland experiment, warming led to a longer growing season and elevated CO2 further extended 39 growing by conserving water, which enabled most species to remain active longer (medium evidence, 40 medium agreement) (Reyes-Fox et al., 2014). | Heritage | 187 - 187 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 43 44 2.4.3.7 Observed Changes in Boreal and Temperate Forests 45 46 The IPCC Fifth Assessment Report found increased tree mortality, wildfire and plant phenology changes in 47 boreal and temperate forests (Settele et al., 2014). Expanding on those conclusions, this Assessment, using 48 analyses of causal factors, attributes to anthropogenic climate change the following observed changes in boreal and temperate forests in the 20th and 21st 49 centuries: upslope and poleward biome shifts at sites in Asia, 50 Europe, and North America (Section 2.4.3.2.1); range shifts of plants (Section 2.4.2.1); earlier blooming and 51 leafing of plants (Section 2.4.2.4); poleward shifts in tree-feeding insects (Section 2.4.2.1); increases in 52 insect pest outbreaks (Section 2.4.4.3.3); increases in area burned by wildfire in western North America 53 (Section 2.4.4.2.1); increased drought-induced tree mortality in western North America (Section 2.4.4.3.1); 54 and thawing of permafrost that underlies extensive areas of boreal forest (IPCC Sixth Assessment Report, 55 Working Group I, Chapter 2, Section 2.4.3.9). Atmospheric CO2 from anthropogenic sources has also 56 increased net primary productivity (Section 2.4.4.5.1). In summary, anthropogenic climate change has 57 caused substantial changes to temperate and boreal forest ecosystems, including biome shifts and increases ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 2 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 2-50 Total pages: 237 1 in wildfire, insect pest outbreaks, and tree mortality, at a global mean surface temperature increase of 0.9º C 2 above the pre-industrial period (robust evidence, high agreement). | Heritage | 188 - 189 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 10 11 For some vegetation changes, land use and land management changes have exerted more influence than 12 climate change. These include upslope and poleward forest shifts in Europe following abandonment of 13 timber harvesting or livestock grazing (Section 2.4.3.2.2), changes in wildfire in Europe affected by fire 14 suppression, fire prevention, and agricultural abandonment (Section 2.4.4.2.3), and forest species 15 composition changes in Scotland due to nitrogen deposition from air pollution (Hester et al., 2019). Remote 16 sensing suggests that the area of temperate and boreal forests increased in Asia and Europe between 1982 17 and 2016 (Song et al., 2018) and in Canada between 1984 and 2015 (Guindon et al., 2018), but forest 18 plantations and regrowth are probable drivers (Song et al., 2018). | Heritage | 189 - 189 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 55 56 In large lowland tropical peatland basins that are less impacted by anthropogenic activities (i.e., Amazon and 57 Congo river basins), the direct impact of climate change is that of a decreased carbon sink (limited evidence, ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 2 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 2-51 Total pages: 237 1 medium agreement) (Roucoux et al., 2013; Gallego-Sala et al., 2018; Wang et al., 2018a; Dargie et al., 2019; 2 Ribeiro et al., 2021). As for the temperate and boreal regions, climatic drying also tends to promote peat 3 oxidation and carbon loss to the atmosphere (medium evidence, medium agreement) (section 2.3.1.3.4) 4 (Helbig et al., 2020; Zhang et al., 2020). In Europe, increasing mean annual temperatures in the Baltic, 5 Scandinavia, and Continental Europe (Section 12.4.5.1) have led to widespread lowering of peatland water 6 tables at intact sites (Swindles et al., 2019), Sphagnum moss desiccation and die off (Bragazza, 2008; Lees et 7 al., 2019), and increased fire intensity and frequency resulting in rapid carbon loss (Davies et al., 2013; 8 Veraverbeke et al., 2021). Nevertheless, longer growing seasons and warmer, wetter climates have increased 9 carbon accumulation and promoted thick deposits regionally, as reported for some North American sites 10 (limited evidence, medium agreement) (Cai and Yu, 2011; Shiller et al., 2014; Ott and Chimner, 2016). | Heritage | 189 - 190 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 18 In many instances, permafrost degradation triggers thermokarst land subsidence associated with local 19 wetting (robust evidence, high agreement) (Jones et al., 2013; Borge et al., 2017; Olvmo et al., 2020; 20 Olefeldt et al., 2021). Permafrost thaw in peatland-rich landscapes can also cause local drying through 21 increased hydrological connectivity and runoff (Connon et al., 2014). In the first decades following thaw, 22 increases in methane, CO2, and nitrous oxide emissions have been recorded from peatland sites, depending 23 on surface moisture conditions (Schuur et al., 2009; O'Donnell et al., 2012; Elberling et al., 2013; Matveev 24 et al., 2016; Euskirchen et al., 2020; Hugelius et al., 2020). Conversely, some evidence suggests increased 25 peat accumulation after thaw (Jones et al., 2013; Estop-Aragonés et al., 2018; Väliranta et al., 2021). There 26 is also a need to consider the impact of wildfire on permafrost thaw, due to its effect on soil temperature 27 regime (Gibson et al., 2018), wildfire as a}, as fire intensity and frequency have increased across the boreal 28 and Arctic biomes (limited evidence, high agreement) (Kasischke et al., 2010; Scholten et al., 2021). | Heritage | 190 - 190 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 24 25 Up through the IPCC Fifth Assessment Report (Settele et al., 2014), detection and attribution analyses had 26 found that anthropogenic climate change, with global temperature increases of 0.3°-0.9ºC above the pre- 27 industrial period and increases in aridity exceeding the effects of local non-climate change factors, caused 28 three cases of drought-induced tree mortality of up to 20% in the period 1945-2007, in western North 29 America (van Mantgem et al., 2009), the African Sahel (Gonzalez et al., 2012), and North Africa (le Polain 30 de Waroux and Lambin, 2012). Increased wildfire and pest infestations, driven by climate change, also 31 contributed to the North American tree mortality (van Mantgem et al., 2009). In addition, a meta-analysis of 32 published cases found that drought consistent with, but not formally attributed, to climate change, had 33 caused tree mortality at 88 sites in boreal, temperate and tropical ecosystems (Allen et al., 2010), with 49 34 additional cases found by the IPCC Fifth Assessment report (Settele et al., 2014). | Heritage | 197 - 197 |

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| IPCC | IPCC_AR6_WGII_Full_Report | 35 36 Since the IPCC Fifth Assessment Report (Settele et al., 2014), global meta-analyses have found at least 15 37 (Allen et al., 2015) and 25 (Hartmann et al., 2018) additional sites of drought-induced tree mortality around 38 the world. These and other global analyses found more rapid mortality than previously (Allen et al., 2015), 39 rising background mortality (Allen et al., 2015), mortality increasing with drought severity (Greenwood et 40 al., 2017), mortality of tropical trees increasing with temperature (Locosselli et al., 2020), mortality 41 increasing with tree size for many species (Bennett et al., 2015), mortality predominantly at the dry edge of 42 species ranges (Anderegg et al., 2019a), and three-fourths of drought-induced mortality cases leading to a 43 change in the dominant species (Batllori et al., 2020). Multiple non-climate factors contribute to tree 44 mortality, including timber cutting, livestock grazing, and air pollution (Martinez-Vilalta and Lloret, 2016). | Heritage | 197 - 197 |
| IPCC | IPCC_AR6_WGII_Full_Report | Globally, tropical dry forests lost, from all causes, 95,000 km2 45 , 8% of their total area, from 1982 to 2016, the 46 most extensive area of mortality of any biome (Song et al., 2018). | Heritage | 197 - 197 |
| IPCC | IPCC_AR6_WGII_Full_Report | 42 43 In western North America, increased infestations of bark beetles and other tree-feeding insects that benefit 44 from increased winter temperatures (IPCC AR6 WGI 3.3.1.1) and longer growing seasons (IPCC AR6 WGI 45 2.3.4.3.1) have killed drought-stressed trees (Section 2.4.2.1; Anderegg et al., 2015; Kolb et al., 2016; Lloret 46 and Kitzberger, 2018; Redmond et al., 2018; Stephens et al., 2018; Fettig et al., 2019; Restaino et al., 2019; 47 Stephenson et al., 2019). Increasing temperatures have allowed bark beetles to move further north and higher 48 in elevation, survive through the winter at sites where they would previously have died, and reproduce more 49 often (Raffa et al., 2008; Bentz et al., 2010; Jewett et al., 2011; Macfarlane et al., 2013; Raffa et al., 2013; 50 Hart et al., 2017; Stephenson et al., 2019; Teshome et al., 2020; Koontz et al., 2021). Under warmer 51 conditions, some insects that were previously innocuous have become important agents of tree mortality 52 (Stephenson et al., 2019; Trugman et al., 2021). Field observations show mixed effects of bark beetle- 53 induced tree mortality on subsequent fire-caused tree mortality (Andrus et al., 2016; Meigs et al., 2016; 54 Candau et al., 2018; Lucash et al., 2018; Talucci and Krawchuk, 2019; Wayman and Safford, 2021). From 55 1997 to 2018, ~5% of western U.S. forest area died from bark beetle infestations (Hicke et al., 2020). In 56 most circumstances, trees that have been weakened by drought are more vulnerable to being killed by bark 57 beetles (Anderegg et al., 2015; Kolb et al., 2016; Lloret and Kitzberger, 2018; Redmond et al., 2018; ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 2 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 2-60 Total pages: 237 1 Stephens et al., 2018; Fettig et al., 2019; Restaino et al., 2019; Stephenson et al., 2019; Koontz et al., 2021). | Heritage | 198 - 199 |
| IPCC | IPCC_AR6_WGII_Full_Report | 22 23 The Amazon as a whole was a net carbon emitter from 2003 to 2008 (Exbrayat and Williams, 2015; Yang et 24 al., 2018b), primarily due to expansion of agricultural and livestock areas, which caused over two-thirds of 25 deforestation from 1990 to 2005 (De Sy et al., 2015; De Sy et al., 2019). Four sites in the Amazon also 26 showed net carbon emissions from 2010 to 2018, from deforestation and fire (Gatti et al., 2021). In the Amazon, deforestation emitted 0.17 ± 0.05 Gt y-1 27 carbon from 2001 to 2015 (Silva Junior et al., 2020) while fires emitted 0.12 ± 0.14 Gt y-1 28 carbon from 2003 to 2015 (Aragao et al., 2018). An analysis of the Amazon carbon loss from deforestation and degradation estimated a loss of 0.5 Gt y-1 29 from 2010 to 2019, with 30 degradation accounting for three-fourths (Qin et al., 2021). Intact old-growth Amazon rainforest has been a 31 net carbon sink (Hubau et al., 2020) but may have become a net carbon source from 2010 to 2019 (Qin et al., 32 2021). | Heritage | 201 - 201 |
| IPCC | IPCC_AR6_WGII_Full_Report | 14 15 Global terrestrial GPP increased 2% from 1951 to 2010 and continued increasing at least through 2016, with 16 increased atmospheric CO2 showing a greater influence than natural factors (Li et al., 2017; Fernandez- 17 Martinez et al., 2019; Liu et al., 2019a; Cai and Prentice, 2020; Melnikova and Sasai, 2020). Global forest 18 area increased 7% from 1982 to 2016, mainly from forest plantations and regrowth in boreal and temperate 19 forests in Asia and Europe (Song et al., 2018), while regrowth in secondary forests > 20 years old, mainly in boreal, temperate, and sub-tropical regions, generated a net removal of 7.7 Gt y-1 20 CO2 from the atmosphere 21 from 2001 to 2019 (Harris et al., 2021). Vegetation growth that exceeds the modelled CO2 fertilisation, gaps 22 in field data, and incomplete knowledge of plant mortality and soil carbon responses introduce uncertainties 23 into quantifying the magnitude of CO2 fertilisation (Walker et al., 2021). A combination of CO2 fertilisation 24 of global vegetation and secondary forest regrowth has increased global vegetation productivity (medium 25 evidence, medium agreement). | Heritage | 202 - 202 |
| IPCC | IPCC_AR6_WGII_Full_Report | 57 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 2 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 2-65 Total pages: 237 1 Field research since the IPCC Fifth Assessment Report has detected biome shifts at numerous sites, 2 poleward and upslope, that are consistent with increased temperatures and altered precipitation patterns 3 driven by climate change, and support prior studies that attributed such shifts to anthropogenic climate 4 change (high confidence). These new studies help fill prior geographic and habitat gaps, for example 5 documenting upward shifts in the forest/alpine tundra ecotone in the Andes, Tibet and Nepal, and northward 6 shifts in the deciduous/boreal forest ecotones in Canada. Globally, woody encroachment into open areas 7 (grasslands, arid regions and tundra) is likely being driven by climate change and increased CO2 in concert 8 with changes in grazing and fire regime (medium confidence) (Section 2.4.3). | Heritage | 203 - 204 |

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|---|---|---|---|---|
| IPCC | IPCC_AR6_WGII_Full_ Report | 12 Analyses of causal factors have attributed increasing tree mortality at sites in Africa and North America to 13 anthropogenic climate change and field evidence has detected tree mortality from drought, wildfire, and 14 insect pests in temperate and tropical forests around the world (high confidence). Water stress, leading to 15 plant hydraulic failure, is the a principal mechanism of drought-induced tree mortality, along with indirect 16 effects of climate change mediated through community interactions (high confidence) ( Section 2.4.4.3). | Heritage | 204 - 204 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 17 18 Terrestrial ecosystems sequester and store globally critical stocks of carbon but these stocks are at risk from 19 deforestation and climate change (high confidence). Tropical deforestation, draining, and burning of 20 peatlands produce almost all of the carbon emissions from land use change. In the Arctic, increased 21 temperatures have thawed permafrost at numerous sites, dried some areas, and increased fire, causing net 22 emissions of carbon from soils (high confidence) (Sections 2.4.4.4, 2.5.3.4). | Heritage | 204 - 204 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 23 24 Globally, increases in temperature, aridity, and drought have increased the length of fire seasons and doubled 25 potentially burnable area (medium confidence). Increases in burnt area have been attributed to anthropogenic 26 climate change in North America (high confidence). In parts of Africa, Asia, Australia, and South America, 27 area burned have also increased, consistent with anthropogenic climate change. Deforestation, peat burning, 28 agricultural expansion or abandonment, fire suppression, and inter-decadal cycles, strongly influence fire 29 occurrence. Areas with the greatest increases in fire season length include the Amazon, western North 30 America, western Asia, and East Africa. (Section 2.4.4.2) 31 32 The changes we have observed, and project to continue, in biodiversity and ecosystem health pose a risk of 33 declines in human health and well-being: e.g. tourism, recreation, food, livelihoods and quality of life 34 (medium confidence). Clear attribution of these impacts is often not possible, but inference can be made by 35 comparison of observed changes in biodiversity / ecosystem health and known services from those particular 36 ecosystems. | Heritage | 204 - 204 |
| IPCC | IPCC_AR6_WGII_Full_ Report | mean surface temperature increases of 0.6- 0.9ºC, has increased the area burned by wildfire over natural levels, increasing burned area up to 11 times in one extreme year and doubling over natural levels in a 32-year period western north America 1984-2017 robust evidence high agreement high confidence Anthropogenic climate change has caused drought-induced tree mortality of up to 20% in three regions, through global mean surface temperature increases of 0.3-0.9ºC above the pre-industrial period and increases in aridity, more than non-climate change factors North America and Africa ca. 1945-2007 medium evidence high agreement medium confidence Anthropogenic climate change has caused latitudinal and elevational vegetation biome shifts in at least 19 sites in boreal, temperate, and tropical ecosystems, between 1700 and 2007, through local temperature increases of 0.4 to 1.6ºC above the pre-industrial period more than non�climate change factors Global 1500-2007 robust evidence high agreement high confidence Anthropogenic climate change and wildfire together have altered vegetation species composition in at least two regions, reducing post-fire natural regeneration and species richness of tree and other plant species, at global mean surface temperature increases of 0.3-0.9ºC western North America, Africa 1966-2015 medium evidence high agreement medium confidence ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 2 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 2-67 Total pages: 237 Beetles & moths shifting poleward and upward has brought new pest species into some forests; warming winters and longer growing season has increased destructive outbreaks of beetles and moths in temperate and boreal forests North America, Europe Varies by study medium-high confidence Exotic species are responding differently from native species in both abundance changes and phenological changes, but not in a consistent fashion North America low/medium evidence low agreement The most cold-adapted species are generally declining in population abundances and contracting their ranges poleward and upward: (e.g. sea-ice dependent, mountain-top restricted, upper headwaters, coldest lakes) Arctic, Himalayas , Antarctic, Alps medium confidence Diseases of both wildlife and humans have emerged into new areas they have not been in historically Global past 20-100 years medium confidence Warming has amplified the trophic state lakes are already in. Eutrophic lakes have become more productive while oligotrophic lakes tend to become more nutrient limited Global Past 20-50 years robust evidence high agreement high/medium confidence Woody encroachment into open (grassland, desert) systems has occurred, with climate change as one of the drivers, along with changes in grazing and other land uses Global medium confidence In boreal, coniferous areas changes in forestry practices and climate change have caused an increase in terrestrial derived dissolved organic matter (DOM) transport into rivers and lakes leading to their browning Boreal Past decades robust evidence high agreement high confidence Climate change induced warming leads to shifts in thermal regime of lakes Global Past decades robust evidence high agreement high confidence Climate change causes gains and losses in freshwater water level Global Past decades limited evidence low confidence Greenhouse gas emissions from freshwater ecosystems are equivalent to around 20% of global burning fossil-fuel CO2 emission Global Past decades medium evidence medium agreement medium/low confidence In lakes weather extremes in wind, temperature, precipitation and loss of ice foremost affect the thermal regime with repercussions on water temperature, transparency, oxygen and nutrient dynamics, affecting ecosystem functionality North America, Europe Varies by study medium/limited evidence high agreement medium/low confidence ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 2 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 2-68 Total pages: 237 Climate change induced warming leads to shifts in thermal regime of rivers and streams; lowland rivers show a stronger thermal response than high-altitude, cold�water receiving streams North America, Europe Past decades robust evidence medium agreement high confidence Loss of biodiversity in streams can be directly attributed to climate change through increased water temperatures, hydrological changes such as increased peak discharges, flow alteration and droughts Global Past decades high agreement | Heritage | 205 - 207 |

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| IPCC | IPCC_AR6_WGII_Full_Report | 43 44 Regional threats from climate change have been reported for 40% of amphibians in China, (Wu, 2020), 33% 45 of European freshwater fish species (Janssen et al., 2016) and 56-69% of Odonates in Australia, (Bush et al., 46 2014b). Assessment of site-specific extirpation likelihoods for 88 aquatic insect taxa projected that climate- 47 change induced hydrological alteration would result in a 30–40% loss of taxa in warmer, drier ecoregions 48 and 10–20% loss in cooler, wetter ecoregions (medium evidence) (Pyne and Poff, 2017). In Africa's 49 Albertine Rift, 51% (n=551) of fish are expected to be impacted by climate change, with 5.5% at high risk 50 due to their sensitivity and poor adaptative capability (high agreement) (Carr et al., 2013). | Heritage | 209 - 209 |
| IPCC | IPCC_AR6_WGII_Full_Report | 15 16 In this Chapter, risk to species, with implications for ecosystems, is assessed using three different 17 approaches. First is an assessment of the geographic distributions of species' losses at different levels of 18 GAST warming, termed 'biodiversity loss, measured as the proportion of species within a given location 19 becoming classified as 'endangered' or 'critically endangered' (sensu IUCN). This measure provides estimates 20 of which sites are at most risk of losing substantial numbers of species locally, leading to degradation of that 21 ecosystems' ability to function. Second is an assessment of risk of proportions of species' becoming extinct 22 globally at different levels of GAST warming, measured using the IUCN criteria for 'critically endangered', 23 and termed 'species' extinction risk'. This measure is closest to assessing the complete loss of a species in the 24 wild, and can be used to compare to past (paleo) extinction rates. Third is an assessment of proportions of 25 species becoming rare or endangered globally (not just locally), and is the foundation for the Burning 26 Embers on biodiversity risk in Figure 2.11. These three approaches provide complementary information of 27 the overall risks to biodiversity and ecosystem integrity under different warming levels. | Heritage | 210 - 210 |
| IPCC | IPCC_AR6_WGII_Full_Report | 29 30 Using data from geological time scales, Song et al. (2021) predicted that a warming of 5.2 °C above pre- 31 industrial would result in mass extinction comparable to that of the five mass extinctions over the past 540 32 My, on the order of 70–85% of species going extinct, in the absence of non-climatic stressor. Mathes et al. | Heritage | 213 - 213 |
| IPCC | IPCC_AR6_WGII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 2 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 2-78 Total pages: 237 1 2 2.5.2.3 Risk to Arid Regions 3 4 Shifts in arid system structure and functioning that have been observed to date (section 2.4.3.3) are projected 5 to continue and include widespread woody plant encroachment, notably in savanna systems in Africa, 6 Australia and South America, and attributed to interacting land use change, climate change, and CO2 7 fertilisation effects (Fensholt et al., 2012a; Fang et al., 2017; Stevens et al., 2017). Arid Mongolian Steppe 8 grassland did not respond to experimentally elevated CO2 (Song et al., 2019). Woody encroachment is 9 projected to continue or not reverse in North American drylands (Caracciolo et al., 2016), and in southern 10 African arid ecosystems (Moncrieff et al., 2014b). Dryland woody encroachment may increase carbon 11 stocks, depending on emissions scenario (Martens et al., 2021), but reduce soil water and biodiversity of 12 grassland-dependent species diversity (Archer et al., 2017). Warm season (C4) grass expansion into arid 13 shrublands risks sudden ecosystem transformation due to introduced wildfire (Bradley et al., 2016), a risk 14 anticipated for grass-invaded desert ecosystems of Australia and south-western United States (Horn and St. | Heritage | 216 - 217 |
| IPCC | IPCC_AR6_WGII_Full_Report | 29 Boreal forests insulate and stabilize permafrost and reduce fluctuations of ground temperature: the amplitude 30 of variation of ground surface temperatures was 28°C in a forested site, compared to 60°C in nearby 31 grassland (Section 2.5.2.7; Bonan, 1989; Stuenzi et al., 2021a; Stuenzi et al., 2021b). Likewise, a shift in 32 moist tropical forests towards vegetation with drought-tolerant traits could possibly reduce 33 evapotranspiration, increase albedo, alter heat transfer at the surface and lead to a negative feedback to 34 precipitation (Section 2.5.2.6; Jia et al., 2019). In savannas, restoration of woody vegetation has been shown 35 to enhance cloud formation and precipitation in response to enhanced transpiration and turbulent mixing, 36 leading to a positive feedback on woody cover (Syktus and McAlpine, 2016). While this has not yet been 37 systematically explored, similar feedbacks might also emerge from a CO2-induced woody cover increase in 38 savannas (low confidence) (Section 2.5.2.5). | Heritage | 234 - 234 |
| IPCC | IPCC_AR6_WGII_Full_Report | 21 22 Tropical lakes tend to be hotspots of freshwater biodiversity (Vadeboncoeur et al., 2011; Brawand et al., 23 2014; Sterner et al., 2020); ancient tropical lakes such as Malawi, Tanganyika, Victoria, Titicaca, Towuti 24 and Matano hold thousands of animal species found nowhere else (Vadeboncoeur et al., 2011). While 25 biodiversity and several ecosystem services can be considered synergistic (food webs, tourism, aesthetical 26 and spiritual value (Langhans et al., 2019), others can be considered antagonistic in case of a strong 27 ecosystem service demand (such as water abstraction, water use, food security in terms of over-exploitation). | Heritage | 237 - 237 |
| IPCC | IPCC_AR6_WGII_Full_Report | 18 19 In addition to "material" and economic services such as eco-tourism, nature also provides cultural services 20 such as recreation, spirituality and well-being. Specifically, being in "direct contact with natural 21 environments" (versus urban environment) has a high positive and causal impact on human well-being (e.g. | Heritage | 243 - 243 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 19 20 2.6.2 Adaptation for Biodiversity Conservation 21 22 A variety of approaches have been identified as potential adaptation measures which people can take to 23 reduce the risks of climate change to biodiversity. (Heller and Zavaleta, 2009 ) (quoted in AR5) identified 24 113 categories of recommendation for adaptation from a survey of 112 papers and reports. Since this time 25 the literature has greatly expanded, with thousands of relevant publications. Whilst there is increasing 26 interest in adaptation for biodiversity conservation and a wide range of plans and strategies, there is less 27 evidence of these plans being implemented. Since AR5 a number of studies, predominantly from Europe and 28 North America, have investigated the extent to which adaptation has been integrated into conservation 29 planning and is being implemented at site and regional scale (Macgregor and van Dijk, 2014; Delach et al., 30 2019; Prober et al., 2019; Clifford et al., 2020; Barr et al., 2021; Duffield et al., 2021). A common pattern in 31 these studies is that vulnerability has been assessed and potential adaptation actions identified, but 32 implementation has been limited beyond actions to improve ecological condition, which may increase 33 resilience at a local scale. | Heritage | 246 - 246 |
| IPCC | IPCC_AR6_WGII_Full_ Report | Hermoso et al. (2016); Thieme et al. (2016); Abell et al. (2017); Brooks et al. (2018) Increase habitat patch size site and expand protected areas Limited evidence High agreement Generally increase resilience because of functioning natural processes, large species populations and refugial areas Eigenbrod et al. (2015); Oliver et al. (2015a) Increase replication and representation of protected areas Limited evidence, High agreement Various benefits inferred, including, wider range of climatic and other conditions, less risk of extreme events affecting many rather than few areas. More sites available for colonisation by range expanding species and better conditions to maintain species in situ under range contraction. | Heritage | 247 - 247 |
| IPCC | IPCC_AR6_WGII_Full_ Report | (2012); Patino-Martinez et al. (2012); Thomas et al. (2016) Restoring hydrological processes of wetlands, rivers and catchments, including by raising water tables and restoring original channels of watercourses, Medium evidence, High agreement Wetland restoration is well established as a conservation measure in some countries. Can reduce vulnerability to drought with climate change but evidence to demonstrate effectiveness as an adaptation measure is limited and requires long-term monitoring of a range of sites. Little restoration of degraded tropical peatlands to date Carroll et al. (2011); Hossack et al. (2013); Dokulil (2016); Timpane-Padgham et al. | Heritage | 247 - 247 |
| IPCC | IPCC_AR6_WGII_Full_ Report | Christmas et al. (2016) Adjusting conservation strategies and site objectives to reflect changing species distributions and habitat characteristics Robust evidence, High Agreement Conservation management will need to take account of changes that cannot be prevented, for example in the distribution of species and composition of communities, in order to protect and manage biodiversity as effectively as possible in a changing climate. | Heritage | 248 - 248 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 28 Within freshwater environments, connectivity of watercourses is essential. Fluvial corridors are necessary to 29 ensure migrating fish population survival, even without climate change; with climate change, connectivity 30 becomes crucial for relatively cold-adapted organisms to migrate upstream to colder areas. Connectivity is 31 also important for the larvae of benthic invertebrates to be able to drift downstream and hence to disperse 32 (Brooks et al., 2018); for adult benthic invertebrates, riparian and terrestrial habitat features can potentially 33 affect dispersal. Connectivity within river and wetland systems for some species can also mediated by more 34 mobile animal species such as fish and birds (Martín-Vélez et al., 2020) Which factors are the most 35 important in either promoting their colonisation of new sites or persisting in situ will differ between species 36 and locations. Some general principle have been recognised and can guide conservation policy and practice 37 (England and RSPB, 2020; Stralberg et al., 2020) but this will often require additional investigation and 38 planning based on understanding individual the niche of specific species. | Heritage | 249 - 249 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 39 40 Managed, translocation by moving species from areas where the climate is becoming unsuitable to places 41 where there persistence under climate change is more likely has been discussed as an adaptation option for 42 many years. So far there have been very few examples of this and it is likely to be a last resort in most cases 43 as in many cases it requires a large investment of resources, the outcome is uncertain and there may be 44 adverse impacts on receiving sites. Nevertheless there are cases where it may be a be a viable option 45 (Stralberg et al., 2019). This is discussed in more detail as a case study in section 2.6.5.1. | Heritage | 249 - 249 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 17 18 Protected areas—areas of land set aside for species and habitat protection with legal protection from 19 development or exploitation—have been a cornerstone of nature conservation for many years. Their 20 effectiveness under a changing climate has been the subject of debate and investigation. There is now a large 21 body of evidence demonstrating that colonisations by range shifting species are more likely to occur on 22 protected sites compared to non-protected sites for a wide range of taxa (e.g. Thomas et al., 2012b; 23 Gillingham et al., 2015), including across continents (Pavón-Jordán et al., 2020a). This is probably because 24 by protecting large areas of natural and semi-natural habitats they provide suitable places for colonising 25 species (Hiley et al., 2013) which may not be available in the surrounding landscape. Although the evidence 26 for protected areas being associated with reduced extinctions is weaker, the finding in Gillingham et al. | Heritage | 250 - 250 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 27 (2015) that protected sites were associated with reduced extinction rates at low latitudes and elevations is 28 strongly suggestive that they can help species' persistence in the face of climate change. | Heritage | 250 - 250 |

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| IPCC | IPCC_AR6_WGII_Full_Report | 49 50 EbA includes a range of different approaches. Examples include restoring coastal and river systems to 51 reduce flood risk and improve water quality and the creation of natural areas within urban areas to reduce 52 temperatures through shading and evaporative cooling. EbA is closely linked with a variety of other concepts 53 such as ecosystem services, natural capital and Disaster Risk Reduction (DRR). EbA was becoming a well- 54 recognised concept at the time of AR5 but implementation was still at an early stage in many cases. Since 55 then pilot studies have been assessed and EbA projects have been initiated around the world. The evidence 56 base continues to grow (Table 2.7) and this has led to increasing confidence in approaches which have been 57 shown to work leading to further expansion in some countries (Table 2.7). However, this is not uniform and ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 2 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 2-112 Total pages: 237 1 there is relatively little synthesis across disciplines and regions (Seddon et al., 2020a). Chausson et al. (2020) 2 used a systematic mapping methodology to characterise 386 published studies. They found that interventions 3 in natural or semi-natural ecosystems ameliorated adverse climate change impacts in 66% of cases, with 4 fewer trade-offs than for more artificial systems such as plantation forest. However, the evidence base has 5 substantial gaps. Most of the evidence has been collected in the Global North and there is a lack of robust, 6 site-specific investigations of the effectiveness of interventions compared to alternatives and of more holistic 7 appraisals accounting for broader social and ecological outcomes. | Heritage | 250 - 251 |
| IPCC | IPCC_AR6_WGII_Full_Report | 6 7 Specific interventions to protect species from climate change, such as the case of South African 8 penguins(Section 2.6.5.5) and the Tasmanian Wilderness World Heritage Area (Section 2.6.5.8), are rare. | Heritage | 261 - 261 |
| IPCC | IPCC_AR6_WGII_Full_Report | 17 18 Adaptation is widely recognised as important for national conservation policy and is being considered in a 19 variety of countries (Section 2.6.5.2, 2.6.5.3). Adaptation in this strategic context includes decisions about 20 the selection and objectives for protected areas, for example identifying places which can act as refugia. It 21 can also mean recognising where protected areas remains important but will support a changing range of 22 species and ecosystems. This is important for directing resources effectively and ensuring that site 23 management remains appropriate. There are however often major uncertainties and the extent to which there 24 will be a need for more radical measures will depend on success in reducing greenhouse gas emissions 25 globally. A global rise of 1.5–2°C would require relatively incremental adjustments to conservation 26 management in many parts of the world, but a 3–4°C rise would require radical, transformational changes to 27 maintain many species and ecosystem services (Morecroft et al., 2012). | Heritage | 261 - 261 |
| IPCC | IPCC_AR6_WGII_Full_Report | 28 29 Whilst adaptation strategies for conservation are relatively common, at least at an outline level, 30 implementation is slow in most places. This may partly reflect lack of resources for conservation in many 31 parts of the world; however, another barrier is that people often value protected sites in their present form. | Heritage | 261 - 261 |
| IPCC | IPCC_AR6_WGII_Full_Report | 51 52 Individual cases show that assisted migration can be successful. Anich & Ward (2017) extended the 53 geographic breeding range of a rare bird, Kirtland's warbler, Setophaga kirtlandii, by 225km by using song 54 playbacks to attract migrating individuals. Wadgymar (2015) successfully transplanted an annual legume, 55 Chamaecrista fasciculata, to sites beyond its current poleward range limit, while Liu (2012) found that all 56 but one of 20 orchid species survived when transplanted to higher elevations than their current range limits. | Heritage | 261 - 261 |
| IPCC | IPCC_AR6_WGII_Full_Report | 57 After introducing two British butterfly species to sites ~65 and ~35 km beyond their poleward range ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 2 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 2-123 Total pages: 237 1 margins, Willis (2009) observed that both introduced populations grew, expanded their ranges and survived 2 for at least 8 years. | Heritage | 261 - 262 |
| IPCC | IPCC_AR6_WGII_Full_Report | 3 4 Butterflies have been favoured subjects for assisted migration in response to regional climate warming, since 5 they are easy to move and their range dynamics have been extensively studied. The Chequered Skipper 6 butterfly, Carterocephalus palaemon, became locally extinct in England in the 1970's, in an area not close to 7 either the species' poleward or equatorial range limits. Nonetheless, Maes (2019) consider climate a crucial 8 parameter for re-introduction, using SDMs both for choosing the source population in Belgium and 9 introduction site. | Heritage | 262 - 262 |
| IPCC | IPCC_AR6_WGII_Full_Report | 16 fasciculata were more successful when sourced from the most poleward existing sites, while individuals 17 from more equatorial habitats performed poorly even when artificially warmed (Wadgymar et al., 2015). | Heritage | 262 - 262 |
| IPCC | IPCC_AR6_WGII_Full_Report | 36 37 (Duffield et al., 2021) found that awareness of the need for adaptation was common amongst nature reserve 38 managers and that they were implementing actions that might building resilience to climate change, such as 39 restoring ecosystem processes and reducing fragmentation. . There is a recognition that it will be necessary 40 to change management objectives of protected sites to adjust to changing circumstances but there was little 41 implementation of such changes (Duffield et al., 2021). The main examples of managing change, was at the 42 coast where rising sea level is causing transitions from terrestrial and freshwater systems to coastal and 43 marine ones. | Heritage | 262 - 262 |

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|---|---|---|---|---|
| IPCC | IPCC_AR6_WGII_Full_ Report | 37 38 Increasing heat wave frequency and intensity recorded in recent decades presents a second threat (van 39 Wilgen and Wannenburgh, 2016; Van Wilgen et al., 2016; Mbokodo et al., 2020). Nests were historically 40 built in insulated guano burrows, but are now frequently sited on open ground (Kemper et al., 2007; 41 Pichegru et al., 2012; Sherley et al., 2012). High temperatures frequently expose the birds to severe heat 42 stress, causing adults to abandon nests and resulting in mortality of eggs and chicks (Frost et al., 1976; 43 Shannon and Crawford, 1999; Pichegru et al., 2012).Intensifying storm surges and greater wave heights can 44 cause nest flooding (Randall et al., 1986; de Villiers, 2002). | Heritage | 264 - 264 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 45 46 The African penguin's survival in the wild is dependent on the success of adaptation action. Increasing 47 access to food resources is a management priority (IUCN, 2018). One approach is to reduce fishing pressure 48 immediately around breeding colonies. An experiment excluding fishing around colonies since 2008 has 49 demonstrated positive effects (Pichegru et al., 2010; Pichegru et al., 2012; Sherley et al., 2015; Sherley et al., 50 2018; Campbell et al., 2019b). A second approach is to establish breeding colonies closer to their prey. An 51 ongoing translocation initiative aims to entice birds eastwards to recolonise an extinct breeding colony and 52 potentially to establish a new one (Schwitzer et al., 2013; Sherley et al., 2014; International, 2018). Penguin 53 "look-alikes" or decoys, constructed from rubber and concrete, have been placed at the extinct colony site 54 and, along with call play-backs, give the illusion of an established penguin colony (Morris and Hagen, 55 2018). This approach has not yet proven successful. | Heritage | 264 - 264 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 56 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 2 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 2-126 Total pages: 237 1 To promote on-site adaptation to heat extremes and flooding, initiatives are underway to provide cooler 2 nesting sites that also provide storm protection and are sufficiently above the high water level (Extinction, 3 2018; International, 2018). Artificial nest boxes of various designs and constructed from a range of materials 4 have been explored in combination with use of natural vegetation. Some designs have proven successful, 5 increasing breeding success (Kemper et al., 2007; Sherley et al., 2012), but the same designs have had less 6 success at other locations (Pichegru, 2013; Lei et al., 2014). | Heritage | 264 - 265 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 7 8 Hand-rearing and releasing African penguin chicks, including from eggs, has long proven valuable because 9 moulting parents, being shore-bound, are unable to feed late-hatching chicks. Since 2006, over 7,000- 10 orphaned chicks have been released into the wild as part of the Chick Bolstering Project with a success rate 11 of 77% (Schwitzer et al., 2013; Sherley et al., 2014; Klusener et al., 2018; SANCCOB, 2018). A new project 12 at Boulders Beach aims to use real-time weather station data, within-nest temperatures and known thresholds 13 of penguin heat stress as triggers for implementing a Heat Wave Response Plan. Drawing on well- 14 established chick-rearing facilities and a large body of expertise, this includes removing heat-stressed eggs 15 and birds, hand rearing and/or rehabilitation and release. It is hoped that such birds may be released at the 16 proposed new colony site. | Heritage | 265 - 265 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 39 40 2.6.5.8 Case Study: Protecting Gondwanan refugia against fire in Tasmania, Australia 41 42 Scale: Local 43 Issue: Protection of rare endemic species 44 45 The Tasmanian Wilderness World Heritage Area (TWWHA) has a high concentration of 'paleo-endemic' 46 plant species restricted to cool, wet climates and fire free environments, but recent wildfires have burnt 47 substantial stands, which are unlikely to recover (Harris et al., 2018b, Bowman et al., 2021, The 2016 48 Tasmanian). The fires led to government inquiries and a fire-fighting review, which have suggested changes 49 to management as that climate change will make such fires more likely in the future (Council, 2016; Press, 50 2016; Council, 2019). | Heritage | 266 - 266 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 14 15 The TWWHA Management Plan (2016) emphasises Aboriginal fire management as an important value of 16 the area, along with their knowledge of plants, animals, marine resources, minerals (ochre and rock sources), 17 and their connection with the area as a living and dynamic landscape. Fire management planning aims to 18 protect important sites from fire and ensure that management does not impact Aboriginal cultural values 19 (DPIPWE, 2016). Increasingly, there is an acknowledgment that the cessation of traditional fire uses has led 20 to changes in vegetation and calls to incorporate Aboriginal burning knowledge into fire management of the 21 TWWHA. | Heritage | 267 - 267 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 22 23 2.6.5.9 Case Study: Bhojtal Lake, Bhopal, India 24 25 Scale: Local 26 Issue: Protection of water resources and biodiversity 27 28 The city of Bhopal, the capital of Madhya Pradesh state in central India, is dependent on Bhojtal, a large 29 man-made lake bordering the city, for its water supply (Everard et al., 2020). It is also an important 30 conservation site with wetlands protected under the Ramsar convention and diverse flora and fauna (WWF, 31 2006). Bhojtal also provides a wide range of other benefits to people, including tourism, recreation, 32 navigation, and subsistence and commercial fisheries, supporting the livelihoods of many families (Verma, 33 2001). | Heritage | 267 - 267 |

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| Organisation | Document | Quotation Content | Codes | Page |
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| IPCC | IPCC_AR6_WGII_Full_Report | 56 57 Blue Carbon ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 2 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 2-135 Total pages: 237 1 2 Blue Carbon ecosystems (mangroves, saltmarshes and seagrass meadows; see glossary) often have high rates 3 of carbon accumulation and sequestration (Section 3.5.5.5; Macreadie et al., 2019). However, quantification 4 of their overall mitigation value is difficult due to variable production of CH4 and N2O (Adams et al., 2012; 5 Rosentreter et al., 2018; MacLean et al., 2019b), uncertainties regarding the provenance of carbon 6 accumulated (Macreadie et al., 2019), and the release of CO2 by biogenic carbonate formation in seagrass 7 ecosystems (Saderne et al., 2019). Therefore, blue carbon strategies, referring to climate change mitigation 8 and adaptation actions based on conservation and restoration of blue carbon ecosystems, can be effective 9 NbS, with evidence of recovery in carbon stocks following restoration, although their global or regional 10 carbon sequestration potential and net mitigation potential may be limited (medium confidence) (Sections 11 3.6.3.1.6; 13.4.3, AR6 WGI 5.6.2.2.2; Duarte et al., 2020). They can also significantly attenuate wave 12 energy, raise the seafloor thus counteracting sea level rise effects, and buffer storm surges and flooding 13 erosion (high confidence) (Sections 13.2.2; 13.10.2). Additionally, they provide a suite of cultural (for 14 example, tourism, livelihood and well-being for native and local communities), provision (e.g. mangrove 15 woods, edible fish and shellfish) and regulation (e.g. nutrient cycling) services (high confidence) (Section 16 3.5.5.5). These services have motivated the implementation of management and conservation strategies of 17 these ecosystems (Sections 3.6.3.1.6; 13.4.2). Blue carbon strategies are relatively new, with many of them 18 experimental and small scale; therefore there is limited evidence of their long-term effectiveness. There is 19 also limited information on the potential emission of other GHGs from restored blue carbon ecosystems, 20 although reconnecting hydrological flow in mangroves and saltmarsh restoration are effective interventions 21 to reduce CH4 and CO2 (limited evidence, medium agreement) (Kroeger et al., 2017; Al-Haj and Fulweiler, 22 2020). | Heritage | 273 - 274 |
| IPCC | IPCC_AR6_WGII_Full_Report | 34 35 AF significantly improves food security and nutrition by increasing access to healthy, diverse diets and 36 rising incomes for food producers, through increased biodiversity of crops, animals, and landscapes (high 37 confidence) (Garibaldi et al., 2016; D'Annolfo et al., 2017; Isbell et al., 2017; Dainese et al., 2019; Bezner 38 Kerr et al. 2021). Livestock mobility improves the site-specific matching of animals' needs with food 39 availability (Damonte et al., 2019; Mijiddorj et al., 2020; Postigo, 2021), and can generate a form of 40 rewilding that restores lost ecosystem functioning (Gordon et al., 2021). Conservation of crop wild relatives 41 in situ supports genetic diversity in crops for the range of future climate scenarios (Redden et al., 2015). | Heritage | 275 - 275 |
| IPCC | IPCC_AR6_WGII_Full_Report | (2020) Urban Ecosystems Urban forests Moderate to High* Moderate Integrated landscape management. Species richness (including exotics) can be high monoculture of an exotic tree lowers resilience and reduces biodiversity Recreation & aesthetics; stormwater absorption benefits; WGII Chapter 06 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 2 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 2-139 Total pages: 237 heat mitigation, air quality improvements Urban wetlands Moderate* Moderate Integrated landscape management. | Heritage | 277 - 278 |
| IPCC | IPCC_AR6_WGII_Full_Report | Recreation & aesthetics; stormwater absorption; heat mitigation; coastal flood protection WGII Chapter 06 Urban grasslands Moderate* Moderate Integrated landscape management fertilized commercial grass monocultures often require irrigation and are less resilient to droughts than native, mixed grasses and forbs Recreation & aesthetics; stormwater absorption; heat mitigation WGII Chapter 06 Open grasslands & savanna Boreal & Temperate Peatlands High Moderate Blocking drainage channels; Raise water level to natural condition; remove planted trees; revegetation of bare peat; No burns; Increases biodiversity resilience; Reduce flood risk Inappropriate hydrological restoration, e.g., flood surface depth greater than natural depth leading to methane emissions Improved water quality in some conditions. | Heritage | 278 - 278 |
| IPCC | IPCC_AR6_WGII_Full_Report | All leads to loss of biodiversity, and resilience; soil erosion; water insecurity Improved grazing potential for livestock and dairy production, sustainable wildlife harvests, Increased water security, income from eco�tourism, medicanal plants, fuel wood. | Heritage | 278 - 278 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | FINAL DRAFT Chapter 3 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 3-4 Total pages: 236 1 aquaculture (high confidence) and reduced capacity of habitat-forming species to protect shorelines (high 2 confidence). {WGI AR6 Chapter 9, 3.2.2.1, 3.4.2.1–3.4.2.5, 3.4.2.7, 3.4.2.10, 3.4.2.3, 3.4.3.3.3, 3.5.3} 3 4 At local to regional scales, climate change worsens the impacts on marine life of non-climate 5 anthropogenic drivers, such as habitat degradation, marine pollution, overfishing and overharvesting, 6 nutrient enrichment, and introduction of non-indigenous species (very high confidence). Although 7 impacts of multiple climate and non-climate drivers can be beneficial or neutral to marine life, most are 8 detrimental (high confidence). Warming exacerbates coastal eutrophication and associated hypoxia, causing 9 'dead zones' (very high confidence), which drive severe impacts on coastal and shelf-sea ecosystems (very 10 high confidence), including mass mortalities, habitat reduction and fisheries disruptions (medium 11 confidence). Overfishing exacerbates effects of multiple climate-impact drivers on predators at the top of the 12 marine food chain (medium confidence). Urbanization and associated changes in freshwater and sediment 13 dynamics increase the vulnerability of coastal ecosystems like sandy beaches, saltmarshes and mangrove 14 forests to sea-level rise and changes in wave energy (very high confidence). Although these non-climate 15 drivers confound attribution of impacts to climate change, adaptive, inclusive, and evidence-based 16 management reduces the cumulative pressure on ocean and coastal ecosystems, which will decrease their 17 vulnerability to climate change (high confidence). {3.3, 3.3.3, 3.4.2.4–3.4.2.8, 3.4.3.4, 3.5.3, 3.6.2, Cross- 18 Chapter Box SLR in Chapter 3} 19 20 Climate-driven impacts on ocean and coastal environments have caused measurable changes in 21 specific industries, economic losses, emotional harm, and altered cultural and recreational activities 22 around the world (high confidence). Climate-driven movement of fish stocks is causing commercial, 23 small-scale, artisanal, and recreational fishing activities to shift poleward and diversify harvests (high 24 confidence). Climate change is increasing the geographic spread and risk of marine-borne pathogens like 25 Vibrio sp. (very high confidence), which endanger human health and decrease provisioning and cultural 26 ecosystem services (high confidence). Interacting climatic impact-drivers and non-climate drivers are 27 enhancing movement and bioaccumulation of toxins and contaminants into marine food webs (medium 28 evidence, high agreement), and increasing salinity of coastal waters, aquifers, and soils (very high 29 confidence), which endangers human health (very high confidence). Combined climatic impact-drivers and 30 non-climate drivers also expose densely populated coastal zones to flooding (high confidence) and decrease 31 physical protection of people, property, and culturally important sites (very high confidence). {3.4.2.10, 32 3.5.3, 3.5.5, 3.5.5.3, 3.5.6, Cross-Chapter Box SLR in Chapter 3} 33 34 Projections: vulnerabilities, risks, and impacts 35 36 Ocean conditions are projected to continue diverging from a pre-industrial state (virtually certain), 37 with the magnitude of warming, acidification, deoxygenation, sea-level rise and other climatic impact- 38 drivers depending on the emission scenario (very high confidence), and to increase risk of regional 39 extirpations and global extinctions of marine species (medium confidence). Marine species richness near 40 the equator and in the Arctic is projected to continue declining, even with less than 2°C warming by the end 41 of the century (medium confidence). In the deep ocean, all global warming levels will cause faster 42 movements of temperature niches by 2100 than those that have driven extensive reorganisation of marine 43 biodiversity at the ocean surface over the past 50 years (medium confidence). "At warming levels beyond 44 2°C by 2100, risks of extirpation, extinction and ecosystem collapse escalate rapidly (high confidence)." 45 Paleorecords indicate that at extreme global warming levels (>5.2°C), mass extinction of marine species may 46 occur (medium confidence). {Box 3.2, 3.2.2.1, 3.4.2.5, 3.4.2.10, 3.4.3.3, Cross-Chapter Box PALEO in 47 Chapter 1} 48 49 Climate impacts on ocean and coastal ecosystems will be exacerbated by increases in intensity, 50 reoccurrence and duration of marine heatwaves (high confidence), in some cases, leading to species 51 extirpation, habitat collapse or surpassing ecological tipping points (very high confidence). Some 52 habitat-forming coastal ecosystems including many coral reefs, kelp forests and seagrass meadows, will 53 undergo irreversible phase shifts due to marine heatwaves with global warming levels >1.5°C and are at high 54 | Heritage | 379 - 381 |

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| Organisation | Document | Quotation Content | Codes | Page |
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| IPCC | IPCC_AR6_WGII_Full_ Report | {3.5, 3.5.2, 3.5.5.3, 3.6, 3.6.2.1, 3.6.3.1, 3.6.3.2, 3.6.3.3, 24 3.6.4.1, 3.6.4.2, 3.6.5, Cross-Chapter Box SLR in Chapter 3, Cross-Chapter Box ILLNESS in Chapter 2} 25 26 Available adaptation options are unable to offset climate-change impacts on marine ecosystems and 27 the services they provide (high confidence). Adaptation solutions implemented at appropriate scales, 28 when combined with ambitious and urgent mitigation measures, can meaningfully reduce impacts 29 (high confidence). Increasing evidence from implemented adaptations indicates that multi-level governance, 30 early-warning systems for climate-associated marine hazards, seasonal and dynamic forecasts, habitat 31 restoration, ecosystem-based management, climate-adaptive management, and sustainable harvesting tend to 32 be both feasible and effective (high confidence). Marine protected areas, as currently implemented, do not 33 confer resilience against warming and heatwaves (medium confidence) and are not expected to provide 34 substantial protection against climate impacts past 2050 (high confidence). However, marine protected areas 35 can contribute substantially to adaptation and mitigation if they are designed to address climate change, 36 strategically implemented, and well governed (high confidence). Habitat restoration limits climate-change 37 related loss of ecosystem services, including biodiversity, coastal protection, recreational use and tourism 38 (medium confidence), provides mitigation benefits on local to regional scales (e.g., via carbon-storing 'blue 39 carbon' ecosystems) (high confidence), and may safeguard fish stock production in a warmer climate 40 (limited evidence). Ambitious and swift global mitigation offers more adaptation options and pathways to 41 sustain ecosystems and their services (high confidence). {3.4.2, 3.4.3.3, 3.5, 3.5.2, 3.5.3, 3.5.5.4, 3.5.5.5, 42 3.6.2.1, 3.6.2.2, 3.6.2.3, 3.6.3.1, 3.6.3.2, 3.6.3.3, 3.6.5, Figure 3.24, Figure 3.25} 43 44 Nature-based solutions for adaptation of ocean and coastal ecosystems can achieve multiple benefits 45 when well-designed and implemented (high confidence), but their effectiveness declines without 46 ambitious and urgent mitigation (high confidence). Nature-based solutions such as ecosystem-based 47 management, climate-smart conservation approaches (i.e., climate-adaptive fisheries and conservation) and 48 coastal habitat restoration can be cost-effective and generate social, economic and cultural co-benefits, while 49 contributing to the conservation of marine biodiversity and reducing cumulative anthropogenic drivers (high 50 confidence). The effectiveness of nature-based solutions declines with warming; conservation and restoration 51 will alone be insufficient to protect coral reefs beyond 2030 (high confidence) and to protect mangroves 52 beyond the 2040s (high confidence). The multi-dimensionality of climate change impacts and their 53 interactions with other anthropogenic stressors calls for integrated approaches that identify trade-offs and 54 synergies across sectors and scales in space and time to build resilience of ocean and coastal ecosystems and 55 the services they deliver (high confidence). {3.4.2, 3.5.2, 3.5.3, 3.5.5.3, 3.5.5.4, 3.5.5.5, 3.6.2.2, 3.6.3.2, 56 3.6.5, Figure 3.25, Table SM3.6} 57 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 3 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 3-7 Total pages: 236 1 Ocean-focused adaptations, especially those that employ nature-based solutions, address existing 2 inequalities, and incorporate just and inclusive decision-making and implementation processes, 3 support the UN Sustainable Development Goals (SDGs) (high confidence). There are predominantly 4 positive synergies between adaptation options for Life Below Water (SDG14), Climate Action (SDG13), and 5 social, economic and governance SDGs (SDG1–12, 16–17) (high confidence), but the ability of ocean 6 adaptation to contribute to the Sustainable Development Goals is constrained by the degree of mitigation 7 action (high confidence). Furthermore, existing inequalities and entrenched practices limit effective and just 8 responses to climate change in coastal communities (high confidence). Momentum is growing towards 9 transformative international and regional governance that will support comprehensive, equitable ocean and 10 coastal adaptation while also achieving SDG14 (robust evidence), without compromising achievement of 11 other SDGs. {3.6.4.0, 3.6.4.2, 3.6.4.3, Figure 3.26}. | Heritage | 382 - 383 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 14 15 The ocean sustains life on Earth by providing essential resources and modulating planetary flows of energy 16 and materials. Together, harvests from the ocean and inland waters provide more than 20% of dietary animal 17 protein for more than 3.3 billion people worldwide and livelihoods for about 60 million people (FAO, 18 2020b). The global ocean is centrally involved in sequestering anthropogenic atmospheric CO2 and recycling 19 many elements, and it regulates the global climate system by redistributing heat and water (WGI AR6 20 Chapter 9, Fox-Kemper et al., 2021). The ocean also provides a wealth of aesthetic and cultural resources 21 (Barbier et al., 2011), contains vast biodiversity (Appeltans et al., 2012), supports more animal biomass than 22 on land (Bar-On et al., 2018), and produces at least half the world's photosynthetic oxygen (Field et al., 23 1998). Ecosystem services (Annex II: Glossary) delivered by ocean and coastal ecosystems support 24 humanity by protecting coastlines, providing nutrition and economic opportunities (Figure 3.1, Selig et al., 25 2019), and providing many intangible benefits. Even though ecosystem services and biodiversity underpin 26 human well-being and support climate mitigation and adaptation (Pörtner et al., 2021b), there are also ethical 27 arguments for preserving biodiversity and ecosystem functions regardless of the beneficiary (e.g., Taylor et 28 al., 2020). This chapter assesses the impact of climate change on the full spectrum of ocean and coastal 29 ecosystems, on their services and on related human activities, and it assesses marine-related opportunities 30 within both ecological and social systems to adapt to climate change. | Heritage | 384 - 384 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 31 32 33 34 Figure 3.1: Estimated relative human dependence on marine ecosystems for coastal protection, nutrition, fisheries 35 economic benefits and overall. Each bar represents an index value that semi-quantitatively integrates the magnitude, 36 vulnerability to loss and substitutability of the benefit. Indices synthesize information on people's consumption of 37 marine protein and nutritional status, gross domestic product, fishing revenues, unemployment, education, governance 38 and coastal characteristics. Overall dependence is the mean of the three index values after standardization from 0–1 39 (Details are found in Table 1 and supplementary material of Selig et al. (2019)). This index does not include the ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 3 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 3-9 Total pages: 236 1 economic benefits from tourism or other ocean industries, and data limitations prevented including artisanal or 2 recreational fisheries or the protective impact of saltmarshes (Selig et al., 2019). Values for reference regions 3 established in the WGI AR6 Atlas (Gutiérrez et al., 2021) were computed as area-weighted means from original 4 country-level data. | Heritage | 384 - 385 |

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| IPCC | IPCC_AR6_WGII_Full_Report | 24 25 Detecting changes and attributing them to specific drivers have been especially difficult in ocean and coastal 26 ecosystems because drivers, responses and scales (temporal, spatial, organizational) often overlap and 27 interact (IPCC, 2014c; IPCC, 2014b; Abram et al., 2019; Gissi et al., 2021). In addition, some marine 28 systems have short, heterogeneous, or geographically biased observational records, which exacerbate the 29 interpretation challenge (Beaulieu et al., 2013; Christian, 2014; Huggel et al., 2016; Benway et al., 2019). It 30 is even more challenging to detect and attribute climate impacts on marine-dependent human systems, where 31 culture, governance and society also strongly influence observed outcomes. To assess climate-driven change 32 in natural and social systems robustly, IPCC reports rely on multiple lines of evidence, and the available 33 types of evidence differ depending on the system under study (Section 1.3.2.1, Cross-Working Group Box 34 ATTRIB). Lines of evidence used for ocean and coastal ecosystems for this and previous assessments 35 include observed phenomena, laboratory and field experiments, long-term monitoring, empirical and 36 dynamical model analyses, Indigenous knowledge (IK) and local knowledge (LK), and paleorecords (IPCC, 37 2014c; IPCC, 2014b; IPCC, 2019b). The growing body of climate research for ocean and coastal ecosystems 38 and their services increasingly provides multiple independent lines of evidence whose conclusions support 39 each other, raising the overall confidence in detection and attribution of impacts over time (Section 1.3.2.1, 40 Cross-Working Group Box ATTRIB in Chapter 3). | Heritage | 386 - 386 |
| IPCC | IPCC_AR6_WGII_Full_Report | 41 The expected frequency of the current one-in-100-year extreme sea level is projected to increase by a median 42 of 20–30 times across tide-gauge sites by 2050, regardless of emission scenario (medium confidence). In 43 addition, extreme-sea-level frequency may be affected by changes in tropical cyclone climatology (low 44 confidence), wave climatology (low confidence), and tides (high confidence) associated with climate change 45 and sea-level change (WGI AR6 Section 9.6.4.2, Fox-Kemper et al., 2021). | Heritage | 396 - 396 |
| IPCC | IPCC_AR6_WGII_Full_Report | 22 23 Detection and attribution of ocean acidification in coastal environments are more difficult than in the open 24 ocean due to larger spatial and temporal variability of carbonate chemistry (Duarte et al., 2013; Laruelle et 25 al., 2017; Torres et al., 2021), and to the influence of other natural acidification drivers such as freshwater 26 and high-nutrient riverine inputs (Cai et al., 2011; Laurent et al., 2017; Fennel et al., 2019; Cai et al., 2020) 27 or anthropogenic acidification drivers (Section 3.1) like atmospherically deposited nitrogen and sulphur 28 (Doney et al., 2007; Hagens et al., 2014). Since AR5, the observing network in coastal oceans has expanded 29 substantially, improving understanding of both the drivers and amplitude of observed variability (Sutton et 30 al., 2016). Recent studies indicate that two more decades of observations may be required before 31 anthropogenic ocean acidification emerges over natural variability in some coastal sites and regions (WGI 32 AR6 Section 5.3.5.2, Sutton et al., 2019; Turk et al., 2019; Canadell et al., 2021). | Heritage | 399 - 399 |
| IPCC | IPCC_AR6_WGII_Full_Report | 22 23 3.3.3.1 Effects of Multiple Drivers on Primary Producers 24 25 Warming and rising CO2 concentrations enhance growth and/or photosynthetic rates in many species of 26 cyanobacteria, picoeukaryotes, coccolithophores, dinoflagellates and diatoms (high confidence) (Fu et al., 27 2007; Sett et al., 2014; Hoppe et al., 2018a; Wolf et al., 2018; Brandenburg et al., 2019), and the optimum 28 pCO2 for growth and/or primary production shifts upward under warming (medium confidence) (Sett et al., 29 2014; Hoppe et al., 2018a). Warming and ocean acidification appear to jointly favour the proliferation and 30 toxicity of harmful algal bloom (HAB) species (limited evidence, high agreement) (Section 3.5.5.3, Bindoff 31 et al., 2019; Brandenburg et al., 2019; Griffith et al., 2019a; Wells et al., 2020), but a 2021 analysis found no 32 uniform global trend in HABs or their distribution over 1985–2018, once field data were adjusted for 33 regional variations in monitoring effort (Hallegraeff et al., 2021). The predominantly detrimental impacts of 34 ocean acidification on coccolithophores can partly be offset by warming (Seifert et al., 2020), but also be 35 exacerbated, depending on the magnitudes of drivers (D'Amario et al., 2020). For non-calcifying 36 macroalgae, responses are highly species-specific and often indicate synergistic interactions between 37 warming and acidification (Kram et al., 2016; Falkenberg et al., 2018). Ocean acidiffcation poses a large risk 38 for coralline algae that is further amplified by warming (medium confidence) (Section 3.4.2.2, Cornwall et 39 al., 2019). However, temperatures up to 5°C above ambient do not decrease calcification (Cornwall et al., 40 2019), and there is limited evidence that some species have the physiological capacity to resist acidification 41 via pH upregulation at the calcification site (Cornwall et al., 2017a). For seagrass, warming beyond a 42 species' thermal tolerance will limit growth and impact germination, but ocean acidification appears to ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 3 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 3-34 Total pages: 236 1 increase thermal tolerance of some eelgrass species by increasing the photosynthesis-to-respiration ratio 2 (medium confidence) (Egea et al., 2018; Scalpone et al., 2020; Zimmerman, 2021). | Heritage | 409 - 410 |
| IPCC | IPCC_AR6_WGII_Full_Report | 44 These investigations could inspire future targeted observational and experimental research to test the validity 45 of model assumptions (Payne et al., 2016; Lotze et al., 2019; Heneghan et al., 2021). The state-of-the-art in 46 such experimental research is presented in Box 3.1. | Heritage | 415 - 415 |
| IPCC | IPCC_AR6_WGII_Full_Report | Coral bleaching and mortality will increase in frequency and magnitude over the next decades (very high confidence). Analysis of the Coupled Model Intercomparison Project 5 ensemble projects the loss of coral reefs from most sites globally by 2050 under mid to high rates of warming (very likely). | Heritage | 418 - 418 |
| IPCC | IPCC_AR6_WGII_Full_Report | communities will differ in species composition and diversity from present reefs (very high confidence). This will greatly diminish the services they provide to society, such as food provision (high confidence), coastal protection (high confidence) and tourism (medium confidence). | Heritage | 419 - 419 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 29 30 In response to the global-scale decline in coral reefs and high future risk, recent literature focuses on finding 31 thermal refuges and identifying uniquely resilient species, populations or reefs for targeted restoration and 32 management (Hoegh-Guldberg et al., 2018b). Reefs exposed to internal waves (Storlazzi et al., 2020), 33 turbidity (Sully and van Woesik, 2020) or warm-season cloudiness (Gonzalez-Espinosa and Donner, 2021) 34 are expected to be less sensitive to thermal stress. Mesophotic reefs (30–150 m) have also been proposed as 35 thermal refugia (Bongaerts et al., 2010), although evidence from recent bleaching events, subsurface 36 temperature records, and species overlap is mixed (Frade et al., 2018; Rocha et al., 2018b; Eakin et al., 2019; 37 Venegas et al., 2019; Wyatt et al., 2020). A study of 2584 reef sites across the Indian and Pacific Oceans 38 estimated that 17% had sufficient cover of framework-building corals to warrant protection, 54% required 39 recovery efforts, and 28% were on a path to net erosion (Darling et al., 2019). There is medium evidence for 40 greater bleaching resistance among reefs subject to temperature variability or frequent heat stress (Barkley et 41 al., 2018; Gintert et al., 2018; Hughes et al., 2018a; Morikawa and Palumbi, 2019), but with trade-offs in 42 terms of diversity and structural complexity (Donner and Carilli, 2019; Magel et al., 2019). There is limited 43 agreement about the persistence of thermal tolerance in response to severe heat stress (Le Nohaïc et al., 44 2017; DeCarlo et al., 2019; Fordyce et al., 2019; Leggat et al., 2019; Schoepf et al., 2020). Recovery and 45 restoration efforts that target heat-resistant coral populations and culture heat-tolerant algal symbionts have 46 the greatest potential of effectiveness under future warming (high confidence) (Box 5.5 in SROCC Chapter 47 5, Bay et al., 2017; Darling and Côté, 2018; Baums et al., 2019; Bindoff et al., 2019; Howells et al., 2021); 48 however, there is low confidence that enhanced thermal tolerance can be sustained over time (Section 49 3.6.3.3.2, Buerger et al., 2020). The effectiveness of active restoration and other specific interventions (e.g., 50 reef shading) are further assessed in Section 3.6.3.3.2. | Heritage | 420 - 420 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 31 32 3.4.2.4 Estuaries, Deltas and Coastal Lagoons 33 34 Estuaries, deltas and lagoons encounter environmental gradients over small spatial scales, generating diverse 35 habitats that support myriad ecosystem services, including food provision, regulation of erosion, nutrient 36 recycling, carbon sequestration, recreation and tourism, and cultural significance (D'Alelio et al., 2021; 37 Keyes et al., 2021). Although these coastal ecosystems have historically been sensitive to erosion-accretion 38 cycles driven by sea level, drought and storms (high confidence) (Peteet et al., 2018; Wang et al., 2018c; 39 Jones et al., 2019b; Urrego et al., 2019; Hapsari et al., 2020; Zhao et al., 2020b), they were impacted for 40 much of the 20th century primarily by non-climate drivers (very high confidence) (Brown et al., 2018b; 41 Ducrotoy et al., 2019; Elliott et al., 2019; He and Silliman, 2019; Andersen et al., 2020; Newton et al., 2020; 42 Stein et al., 2020). Nevertheless, the influence of climate-impact drivers has become more apparent over 43 recent decades (medium confidence) (Table 3.6). | Heritage | 425 - 425 |
| IPCC | IPCC_AR6_WGII_Full_ Report | SROCC (Bindoff et al., 2019; Oppenheimer et al., 2019) Coastal ecosystems, including saltmarshes, mangroves, vegetated dunes and sandy beaches, can build vertically and expand laterally in response to SLR, though this capacity varies across sites (high confidence). These ecosystems provide important services that include coastal protection and habitat for diverse biota. However, because of human actions that fragment wetland habitats and Seagrass meadows (high confidence) will face moderate to high risk at temperature above 1.5°C global sea surface warming. | Heritage | 428 - 428 |
| IPCC | IPCC_AR6_WGII_Full_ Report | Coastal squeeze is expected to accelerate with sea-level rise (SLR). In many locations, finding sufficient sand to rebuild beaches and dunes artificially will become increasingly difficult and expensive as present supplies near project sites are depleted (high confidence). | Heritage | 431 - 431 |
| IPCC | IPCC_AR6_WGII_Full_ Report | SROCC (Bindoff et al., 2019) Coastal ecosystems are already impacted by the combination of SLR, other climate-related ocean changes, and adverse effects from human activities on ocean and land (high confidence). Attributing such impacts to SLR, however, remains challenging due to the influence of other climate-related and non-climate drivers such as infrastructure development and human�induced habitat degradation (high confidence). Coastal ecosystems, including saltmarshes, mangroves, vegetated dunes and sandy beaches, can build vertically and expand laterally in response to SLR, though this capacity varies across sites (high confidence) as a consequence of human actions that fragment wetland habitats and restrict landward migration, coastal ecosystems progressively lose their ability to adapt to climate-induced changes and Sandy beach ecosystems will increasingly be at risk of eroding, reducing the habitable area for dependent organisms (high confidence). | Heritage | 431 - 431 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 9 10 11 For beach fauna, emerging evidence links range shifts, increasing representation by warm-affinity species 12 and mass mortalities to ocean warming (limited evidence, high agreement) (McLachlan and Defeo, 2018; 13 Martin et al., 2019). But even amongst the best-studied taxa, such as turtles, vulnerability to warming (high 14 confidence) and SLR (medium confidence) anticipated on the basis of theory (Poloczanska et al., 2009; Saba 15 et al., 2012; Pike, 2013; Laloë et al., 2017; Tilley et al., 2019) yields only a few detected impacts in the field 16 associated mainly with feminisation (female-skewed sex ratios driven by warmer nest temperatures) (Jensen 17 et al., 2018; Colman et al., 2019; Tilley et al., 2019), phenology (Monsinjon et al., 2019), reproductive 18 success (Bladow and Milton, 2019) and inter-nesting period (Valverde-Cantillo et al., 2019). Moreover, 19 although established vulnerabilities imply high projected future risk for turtles (high confidence) (e.g., 20 Almpanidou et al., 2019; Monsinjon et al., 2019; Patrício et al., 2019; Varela et al., 2019; Santidrián Tomillo 21 et al., 2020), many populations remain resilient to change (Fuentes et al., 2019; Valverde-Cantillo et al., 22 2019; Laloë et al., 2020; Lamont et al., 2020), perhaps because variation in sand temperatures at nesting 23 depth among beaches very likely exceeds the magnitude of warming anticipated by 2100, even under RCP8.5 24 (medium confidence) (Bentley et al., 2020a). As expected for a taxon with a long evolutionary history, turtles 25 display natural adaptation, not only by virtue of broad geographic distributions that include natural climate- 26 change refugia (Boissin et al., 2019; Jensen et al., 2019), but also because some initial responses to warming 27 might counteract anticipated impacts. For example, although feminisation poses a significant long-term risk 28 to turtle populations (high confidence), it might contribute to population growth in the near- to mid-term 29 (medium confidence) (Patrício et al., 2019). Resilience to climate change might be further enhanced by range 30 extensions, alterations in nesting phenology, and fine-scale nest-site selection (medium confidence) (Abella 31 Perez et al., 2016; Santos et al., 2017; Almpanidou et al., 2018; Rivas et al., 2019; Laloë et al., 2020). | Heritage | 433 - 433 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 8 These SES are largely landlocked and are thus heavily influenced by surrounding landscapes, local and 9 global climate-impact drivers, as well as non-climate drivers (Section 3.1), making them highly vulnerable to 10 cumulative threats. Key climate-impact drivers in SES are warming, increasing frequency and duration of 11 MHWs, acidification, and the increasing in size and number of OMZs (Figure 3.12, Hoegh-Guldberg et al., 12 2014). In AR5, SES were recognised as regionally significant for fisheries and tourism, but highly exposed 13 to both local and global stressors, offering limited options for organisms to migrate in response to climate 14 change (Table 3.10). | Heritage | 434 - 434 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 13 14 Similar to other coastal ecosystems, evidence since SROCC (Table 3.11) suggests shelf-sea ecosystems and 15 the fisheries and aquaculture they support are sensitive to the interactive effects of climate-impact drivers, as 16 well as non-climate drivers, including nutrient pollution, sedimentation, fishing pressure and resource 17 extraction (Table 3.12, Figure 3.12). Changes in freshwater, nutrient and sediment inputs from rivers due to 18 both climate and non-climate drivers can influence productivity and nutrient limitation, ecosystem structure, 19 carbon export and species diversity and abundance (Balch et al., 2012; Picado et al., 2014), and can result in 20 reduced water clarity and light penetration (Dupont and Aksnes, 2013; McGovern et al., 2019). Seasonal 21 bottom-water hypoxia occurs in some shelf seas (e.g., northern Gulf of Mexico, Bohai Sea, East China Sea) 22 due to riverine inputs of freshwater and nutrients, promoting stratification, enhanced primary production, and 23 organic carbon export to bottom waters (high confidence) (Zhao et al., 2017; Wei et al., 2019; Del Giudice et 24 al., 2020; Große et al., 2020; Jarvis et al., 2020; Rabalais and Baustian, 2020; Song et al., 2020a; Xiong et 25 al., 2020; Zhang et al., 2020a). | Heritage | 436 - 436 |
| IPCC | IPCC_AR6_WGII_Full_ Report | (Hall, 2002) 5 6 7 Key risks to shelf seas include shifts or declines in marine micro- and macro-organism abundance and 8 diversity driven by eutrophication, HABs and extreme events (storms and MHWs), and consequent effects 9 on fisheries, resource extraction, transportation, tourism and marine renewable energy (Figure 3.12). The 10 combined effects of deoxygenation and warming can affect the metabolism, growth, feeding behaviour and 11 mobility of fish species (Section 3.3.3). The increasing availability of observations mean that ecosystem 12 changes in shelf seas can be increasingly attributed to climate change (high confidence) (Liang et al., 2018; 13 Maharaj et al., 2018; Ma et al., 2019; Meyer and Kröncke, 2019; Bargahi et al., 2020; Bedford et al., 2020; 14 Friedland et al., 2020b; Mérillet et al., 2020). Eutrophication and seasonal bottom-water hypoxia in some 15 shelf seas have been linked to warming (high confidence) (Wei et al., 2019; Del Giudice et al., 2020) and 16 increased riverine nutrient loading (high confidence) (Wei et al., 2019; Del Giudice et al., 2020). Since 17 SROCC, some severe HABs have been attributed to extreme events, such as MHWs (Section 14.4.2, Roberts 18 et al., 2019; Trainer et al., 2019). However, a recent worldwide assessment of HABs attributed the increase 19 in observed HABs to intensified monitoring associated with increased aquaculture production (high 20 confidence) (Hallegraeff et al., 2021). | Heritage | 437 - 437 |
| IPCC | IPCC_AR6_WGII_Full_ Report | Given the high sensitivity of the coupled human-natural EBUS to oceanographic changes, the future sustainable delivery of key ecosystem services from EBUS is at risk under climate change; those that are most at risk in the 21st century include fisheries (high confidence), aquaculture (medium confidence), coastal tourism (low confidence) and climate regulation (low confidence). | Heritage | 440 - 440 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 10 11 Despite low confidence in detailed projections for ecological changes in EBUS, the WGI assessment (WGI 12 AR6 Chapter 9, Fox-Kemper et al., 2021) that upwelling-favourable winds will weaken (or be present for 13 shorter durations) at low latitude but intensify at high latitude (high confidence), albeit by no more than 20% 14 in either case (medium confidence), presents some key risks to associated EBUS ecosystems. These include 15 potential decreases in provisioning services, including fisheries and marine aquaculture (Bertrand et al., 16 2018; Kifani et al., 2018; Lluch-Cota et al., 2018; van der Lingen and Hampton, 2018), and cultural services 17 such as nature-based tourism (Section 3.5). | Heritage | 441 - 441 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | The projected effects of climate-induced stressors on polar marine ecosystems present risks for commercial and subsistence fisheries with implications for regional economies, cultures and the global supply of fish, shellfish, and Antarctic krill (high confidence). | Heritage | 442 - 442 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 1 2 3 Since SROCC, evidence demonstrates that warmer oceans, less sea ice and increased advection results in 4 increasing primary production in the Arctic, albeit with regional variation (high confidence), while trends 5 remain spatially heterogeneous and less clear in the Antarctic (medium confidence) (Cross-Chapter Paper 6, 6 Del Castillo et al., 2019; Lewis et al., 2020; Pinkerton et al., 2021; Song et al., 2021a). Furthermore, climate 7 warming influences key mechanisms determining energy transfer between trophic levels including: (1) 8 altered size spectra; (2) shifts in trophic pathways; (3) phenological mismatches; and (4) increased top-down 9 trophic regulation (Table 3.15). However, the scale of impacts from changes in these mechanisms on 10 ecosystem productivity in warming polar oceans remains unresolved and is hence assigned low confidence. | Heritage | 442 - 442 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 27 28 Fisheries are largely sustainably managed, yet are expanding polewards following sea-ice melt in the Arctic 29 (high confidence) (Fauchald et al., 2021) and possibly in the Antarctic (limited evidence) (Santa Cruz et al., 30 2018). Tourism is increasing and expanding in both polar regions, while shipping and hydrocarbon 31 exploration are growing in the Arctic, increasing the risks of compound effects on vulnerable and already 32 stressed populations and ecosystems (high confidence) (Sections 3.6.3.1.3, 3.6.3.1.4, Cross-Chapter Paper 6, 33 Hauser et al., 2018; Meredith et al., 2019; Helle et al., 2020; Rogers et al., 2020; Cavanagh et al., 2021). | Heritage | 444 - 444 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 23 24 The paleo record confirms that marine biodiversity has been vulnerable to climate warming both globally 25 and regionally (very high confidence) (Cross-Chapter Box PALEO in Chapter 1, Stanley, 2016). In extreme 26 cases of warming (e.g., >5.2°C), marine mass extinctions occurred in the geological past, and there may be a 27 relationship between warming magnitude and extinction toll (medium confidence) (Song et al., 2021b). A 28 combination of warming and spreading anoxia caused marine extinctions in ancient episodes of rapid climate 29 warming (high confidence) (Bond and Grasby, 2017; Benton, 2018; Penn et al., 2018; Them et al., 2018; 30 Chen and Xu, 2019). The role of ocean acidification in ancient extinctions is yet to be resolved (low 31 confidence) (Clapham and Payne, 2011; Clarkson et al., 2015; Jurikova et al., 2020; Müller et al., 2020). | Heritage | 455 - 455 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 9 Similar patterns among marine animals have been described previously for historical warming events (Song 10 et al., 2020b). Tropicalisation is associated with increased representation of herbivorous species (Vergés et 11 al., 2016; Zarco-Perello et al., 2020; Smith et al., 2021), although observations and theory suggest that 12 dietary generalism can also favour range-shifting species (Monaco et al., 2020; Wallingford et al., 2020). | Heritage | 457 - 457 |
| IPCC | IPCC_AR6_WGII_Full_ Report | Supporting and Regulating Habitat creation and maintenance Status of nesting, feeding, nursery, and mating sites for birds, mammals, and other marine life, and of resting and overwintering places for migratory marine life or insects. Connectivity of ocean habitats. | Heritage | 475 - 475 |
| IPCC | IPCC_AR6_WGII_Full_ Report | Supporting identities Existence of and access to cultural, heritage, and religious activities, and opportunities for intergenerational knowledge transfer. Sense of place. | Heritage | 476 - 476 |
| IPCC | IPCC_AR6_WGII_Full_ Report | Ecosystem service and chapter subsection Observed Impacts Projected Impacts All (Section 3.5) Climate change has affected marine "ecosystem services with regionally diverse outcomes, challenging their governance (high confidence). Both positive and negative impacts result for food security through fisheries (medium confidence), local cultures and livelihoods (medium confidence), and tourism and recreation (medium confidence). The impacts on ecosystem services have negative consequences for health and well-being (medium confidence), and for Indigenous Peoples and local communities dependent on fisheries (high confidence) (1.1, 1.5, 3.2.1, 5.4.1, 5.4.2, Figure SPM.2)" (SROCC SPM A.8, IPCC, 2019c). | Heritage | 477 - 477 |
| IPCC | IPCC_AR6_WGII_Full_ Report | Food provision (Section 3.5.3) "Warming-induced changes in the spatial distribution and abundance of some fish and shellfish stocks have had positive and negative impacts on catches, economic benefits, livelihoods, and local culture (high confidence). There are negative consequences for Indigenous Peoples and local communities that are dependent on fisheries (high confidence). Shifts in species distributions and abundance has challenged international and national ocean and fisheries governance, including in the Arctic, North Atlantic and Pacific, in terms of regulating fishing to secure ecosystem integrity and sharing of resources between fishing entities (high confidence) (3.2.4, 3.5.3, 5.4.2, 5.5.2, Figure SPM.2)". (SROCC SPM A.8.1 IPCC, 2019c). | Heritage | 477 - 477 |
| IPCC | IPCC_AR6_WGII_Full_ Report | "[Risks from marine-borne pollutants and pathogens] are projected to be particularly large for human communities with high consumption of seafood, including coastal Indigenous communities (medium confidence), and for economic sectors such as fisheries, aquaculture, and tourism (high confidence) (3.4.3, 5.4.2, Box 5.3)" (SROCC SPM B.8.3, IPCC, 2019c). | Heritage | 479 - 479 |
| IPCC | IPCC_AR6_WGII_Full_ Report | "Since the early 1980s, the occurrence of harmful algal blooms (HABs) and pathogenic organisms (e.g., Vibrio) has increased in coastal areas in response to warming, deoxygenation and eutrophication, with negative impacts on food provisioning, tourism, the economy and human health (high confidence)." (SROCC Chapter 5 Executive Summary, Bindoff et al., 2019). | Heritage | 479 - 479 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | Cultural Services (Section 3.5.6) “Climate change impacts on marine ecosystems and their services put key cultural dimensions of lives and livelihoods at risk (medium confidence), including through shifts in the distribution or abundance of harvested species and diminished access to fishing or hunting areas. This includes potentially rapid and irreversible loss of culture and local knowledge and Indigenous knowledge, and negative impacts on traditional diets and food security, aesthetic aspects, and marine recreational activities (medium confidence)” (SROCC SPM B.8.4, IPCC, 2019c). | Heritage | 480 - 480 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 3 Substantial economic losses in the North American Pacific Coast shellfish aquaculture industry in the 2000s 4 assessed in SROCC (Bindoff et al., 2019) and WGII AR5 (Pörtner et al., 2014) remain the clearest example 5 of human harm from ocean acidification. Technology-based adaptations (Section 3.6.3) have minimised 6 aquaculture losses from ocean acidification, including early warning systems to guide hatchery operations 7 and culturing resilient shellfish strains (Section 5.9.4, Barton et al., 2015a). Laboratory studies show that 8 ocean acidification decreases the fitness, growth, or survival of many economically and culturally important 9 larval or juvenile shelled mollusks (high confidence) (Cao et al., 2018; Onitsuka et al., 2018; Stevens and 10 Gobler, 2018; Griffith et al., 2019a; Mellado et al., 2019), and of several valuable wild-harvest crab species 11 (Barton et al., 2015a; Punt et al., 2015; Miller et al., 2016; Swiney et al., 2017; Gravinese et al., 2018; 12 Tomasetti et al., 2018; Long et al., 2019; Trigg et al., 2019). Ocean acidification alters larval settlement and 13 metamorphosis of fish in laboratory studies (high confidence) (Cattano et al., 2018; Espinel-Velasco et al., 14 2018), suggesting possible changes in fish survival and thus fishery characteristics. Deoxygenation can 15 decrease size and abundance of marine species and suppress trophic interactions (Levin, 2003), decrease the 16 diversity within marine ecosystems (Sperling et al., 2016) while temporarily increasing catchability and 17 increasing the risk of overfishing (Breitburg et al., 2018), and decrease the ecosystem services provided by 18 specific fisheries (Orio et al., 2021). The chronic effects of deoxygenation on wild fisheries are complex and 19 highly interactive with co-occurring drivers and overall ecosystem responses (medium evidence, high 20 agreement) (Townhill et al., 2017; Rose et al., 2019). Detecting and attributing marine ecosystem responses 21 to ocean acidification and deoxygenation outside of laboratory studies remains challenging because of the 22 strong influence of co-occurring environmental changes on natural systems (Section 3.3.5, Rose et al., 2019; 23 Doo et al., 2020). | Heritage | 482 - 482 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 3 4 Carbon storage and burial in mangroves, saltmarshes and seagrass meadows (Table Box3.4.1) help regulate 5 ocean and coastal carbon cycling and may contribute to nature-based mitigation, although regional estimates 6 vary widely based on climatic and edaphic conditions (WGIII AR6 Section 7.4). In addition, coastal 7 vegetated ecosystems provide substantial and interdependent regulating, provisioning and cultural ecosystem 8 services. These include disproportionately high biodiversity per unit area (Pörtner et al., 2021a); abundant 9 habitat (Section 3.5.5.1) and nurseries for aquatic, terrestrial, aerial, and microbial species; natural filtration 10 of waste and stormwater runoff into the coastal ocean (Sections 3.5.5.3, 4.2.7, Cross-Chapter Box ILLNESS 11 in Chapter 2); coastal protection (Section 3.5.5.4, Ouyang et al., 2018; Quevedo et al., 2020); food and 12 natural materials (Sections 3.5.3, 3.5.4); and support for tourism, livelihoods, and cultural activities (Section 13 3.5.6). Global estimates of services provided by coastal blue carbon ecosystems depend on the quality of 14 available mapping, which is currently best developed for mangroves (Macreadie et al., 2019), and improving 15 for saltmarshes and seagrasses (McOwen et al., 2017; McKenzie et al., 2020; Young et al., 2021). | Heritage | 488 - 488 |
| IPCC | IPCC_AR6_WGII_Full_ Report | Mangroves Saltmarshes Seagrass meadows Carbon stocks (MgC ha–1 ) 856 ± 64.2 (79–2208) (Kauffman et al., 2020) 317.2 ± 38.2 (27–1900) (Alongi, 2018c) 139.7 (9.1–628) (Fourqurean et al., 2012; Alongi, 2018d) Carbon burial rate (g C m–2 yr–1 ) 194 ± 30 (6.2–1722) (Wang et al., 2020) 168 ± 14 (1.2–1167.5) (Wang et al., 2020) 220.7 ± 40.2 (-2094–2124) (Alongi, 2018d) Global Carbon burial rate (TgC yr–1 ) 41 (Wang et al., 2020) 12.63 (Wang et al., 2020) 35.31 (Alongi, 2020) Global areal coverage (Mha) 13.7 (Richards et al., 2020) 5.5 (McOwen et al., 2017) 16 (McKenzie et al., 2020) 24 25 26 Coastal vegetated ecosystems are vulnerable to harm from multiple climate and non-climate drivers, and 27 together these have reduced wetland area globally (high confidence) (Section 3.4.2.5) and endangered the 28 services provided by these ecosystems (high confidence). Loss of coastal vegetated ecosystems changes 29 biodiversity (Sections 3.5.2, 3.4.2.3–3.4.2.5) (Numbere, 2019; Parreira et al., 2021), increases risk of damage 30 and erosion from SLR and storms (Sections 3.4.2.3–3.4.2.5, Cross-Chapter Box SLR in Chapter 3, Galeano 31 et al., 2017), and impacts provisioning (Sections 3.5.3–3.5.4, Li et al., 2018b; Maina et al., 2021). These 32 changes also strongly determine the quantity and longevity of blue carbon storage (high confidence) 33 (Macreadie et al., 2019; Lovelock and Reef, 2020). Specific site characteristics and ecosystem responses to 34 climate change will determine future local blue carbon storage or loss (high confidence) (Table Box3.4.2). | Heritage | 488 - 488 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 22 23 Additional evidence since previous assessments (Table 3.26) confirms that climate-change impacts on ocean 24 and coastal cultural ecosystem services have already disrupted people's place-based emotional attachments 25 and cultural activities (limited evidence, high agreement) (Figure 3.22). Bleaching and mortality of corals in ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 3 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 3-115 Total pages: 236 1 the Great Barrier Reef have induced measurable "reef grief," a type of solastalgia, among reef visitors and 2 researchers (Conroy, 2019; Curnock et al., 2019; Marshall et al., 2019). The mental health of people in 3 Tuvalu (Gibson et al., 2020), Alaska (Allen, 2020), and Honduras (Kent and Brondo, 2020) have suffered 4 from both the experience of climate impacts on ocean and coastal ecosystems (e.g., SLR and changes in 5 fisheries and wildlife), and the anticipation of more in the future. The climate-associated MHWs and harmful 6 algal bloom events in 2014–2016 in the US Pacific Northwest (Moore et al., 2019) prevented seasonal razor 7 clam harvests culturally important to Indigenous Peoples and the local community (Section 3.5.5.3, Crosman 8 et al., 2019). SLR and storm-driven coastal erosion endanger coastal archaeological and heritage sites around 9 the world (very high confidence) (Hoque and Hoque, 2008; Carmichael et al., 2018; Reimann et al., 2018; 10 Elliott and Williams, 2019; Ravanelli et al., 2019; Anzidei et al., 2020; Chemeli et al., 2020; García Sánchez 11 et al., 2020; Harkin et al., 2020; Hil, 2020; Rivera-Collazo, 2020). | Heritage | 490 - 491 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 25 floating macroalgae from the central Atlantic Ocean and Caribbean Sea, whose proliferation has been 26 attributed to high sea surface temperatures and nutrient enrichment (Wang et al., 2019a), has substantially 27 disrupted beach tourism in the Caribbean and Mexico and imposes millions of dollars of clean-up costs 28 annually on affected beaches (Milledge and Harvey, 2016). | Heritage | 491 - 491 |
| IPCC | IPCC_AR6_WGII_Full_ Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 3 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 3-119 Total pages: 236 1 2 3 3.6.2.1 Socio-Institutional Adaptation 4 5 Increasing evidence shows that an effective solution portfolio includes social and institutional adaptation 6 (Figure 3.23, top; Table 3.28). Social adaptation to climate change is already occurring, as people use 7 strategies ranging from accommodating change, to coping, adapting and transforming their livelihoods (Béné 8 and Doyen, 2018; Fedele et al., 2019; Galappaththi et al., 2019; Barnes et al., 2020; Ojea et al., 2020; Green 9 et al., 2021c). Although management and institutions have major roles in adaptation (Gaines et al., 2018; 10 Barange, 2019), marine governance is impeded by increasing numbers of often-competing users and uses 11 (Boyes and Elliott, 2014); sector-led, fragmented, efforts (Nunan et al., 2020); and a legal framework less 12 clear than those on land (Crespo et al., 2019; Guggisberg, 2019). Future social responses depend on warming 13 levels and on the institutional, socio-economic and cultural constructs that allow or limit livelihood changes 14 (medium confidence) (Chapter 18, Galappaththi et al., 2019; Ford et al., 2020; Green et al., 2021c). Both 15 social and institutional transformations are needed to change the structures of power, culture, politics and/or 16 identity associated with marine ecosystems (Section 1.5.2, Wilson et al., 2020b). Ideally, institutional and 17 social adaptation will work together to sustain knowledge systems and education, enhance participation and 18 social inclusion, facilitate livelihood support and transformational change of dependent coastal communities, 19 provide economic and financial instruments, and include polycentric and multi-level governance of 20 transboundary management (Fedele et al., 2019; Fulton et al., 2019). | Heritage | 494 - 495 |
| IPCC | IPCC_AR6_WGII_Full_ Report | Livelihood diversification Medium confidence Livelihood diversification in communities dependent on marine and coastal ecosystems reduces climate risks and confers flexibility (Blanchard et al., 2017; Cinner and Barnes, 2019; Mohamed Shaffril et al., 2020; Owen, 2020; Pinsky, 2021; Taylor et al., 2021) Fisheries and mariculture (Section 3.6.3.1.2), coastal communities (Cross�Chapter Box SLR in Chapter 3), tourism (Section 3.6.3.1.3) ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 3 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 3-120 Total pages: 236 to individuals, which is key to adaptive capacity. | Heritage | 495 - 496 |
| IPCC | IPCC_AR6_WGII_Full_ Report | (Nurhidayah and McIlgorm, 2019) Climate services (Section 3.6.3.4.3), tourism cruise ship sector (Section 3.6.3.1.3) Multi-level ocean governance High confidence The multi-scale nature of ocean and coastal climate-change risk demands adaptation solutions at multiple levels of governance that consider the objectives and perceptions of all stakeholders to support local implementation of broad strategies. | Heritage | 496 - 496 |
| IPCC | IPCC_AR6_WGII_Full_ Report | (Rosendo et al., 2018; Tittensor et al., 2019; Frazão Santos et al., 2020; Rilov et al., 2020; Pinsky et al., 2021) Tourism (Section 3.6.3.1.3), conservation, (Section 3.6.3.2.1.) Sustainable harvesting High confidence Sustainable harvesting is a nature-based solution (NbS) that contributes to adaptation by safeguarding the provision of marine food and cultural services, while reducing the ecological vulnerability of marine ecosystems. | Heritage | 499 - 499 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 51 52 53 Sea-level rise (SLR) is already impacting ecosystems, human livelihoods, infrastructure, food security and 54 climate mitigation at the coast and beyond. Ultimately, it threatens the existence of cities and settlements in 55 low lying areas, and some island nations and their cultural heritage (Chapters 9– 15, Cross-Chapter Paper 2 56 and 4 Oppenheimer et al., 2019). The challenge can be addressed by mitigation of climate change and coastal 57 adaptation. | Heritage | 501 - 501 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 11 12 At centennial timescales, projected SLR represents an existential threat for island nations, low-lying coastal 13 zones, and the communities, infrastructure, and cultural heritage therein (Chapters 9–15, Cross-Chapter 14 Paper 4). Even if climate warming is stabilised at 2°C to 2.5°C GWL, coastlines will continue to reshape 15 over millennia, affecting at least 25 megacities and drowning low-lying areas where 0.6–1.3 billion people 16 lived in 2010 (medium confidence) (WGI AR6 Chapter 9 Marzeion and Levermann, 2014; Clark et al., 2016; 17 Kulp and Strauss, 2019; Fox-Kemper et al., 2021; Strauss et al., 2021). | Heritage | 503 - 503 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 4 5 Ecosystem-based adaptation can reduce impacts on human settlements and bring substantial co-benefits such 6 as ecosystem services restoration and carbon storage, but they require space for sediment and ecosystems 7 and have site-specific physical limits, at least above 1.5°C GWL (high confidence) (Cross-Chapter Box 8 NATURAL in Chapter 2, Chapters 3, 9, 11, 15, Herbert et al., 2015; Brown et al., 2019; Van Coppenolle and 9 Temmerman, 2019; Watanabe et al., 2019; Neijnens et al., 2021). For example, planting and conserving 10 vegetation helps sediment accumulation by dissipating wave energy and reducing impacts of storms, at least 11 at present-day sea levels (high confidence) (Temmerman et al., 2013; Narayan et al., 2016; Romañach et al., 12 2018; Laengner et al., 2019; Leo et al., 2019). Coastal wetlands and ecosystems can be preserved by 13 landward migration (Schuerch et al., 2018; Schuerch et al., 2019) or sediment supply (VanZomeren et al., 14 2018), but they can be seriously damaged by coastal defences designed to protect infrastructure (Chapters 3, 15 13, Cooper et al., 2020b). Sediment nourishment can prevent erosion, but it can also negatively impact beach 16 amenities and ecosystems through ongoing dredging, pumping and deposition of sand and silts (VanZomeren 17 et al., 2018; de Schipper et al., 2021; Harris et al., 2021). | Heritage | 504 - 504 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 35 36 3.6.3.1.3 Tourism 37 Coastal areas, coastal infrastructure and beaches, sustaining tourism that contributes significantly to local 38 economies (James et al., 2019; Ruiz-Ramírez et al., 2019), are under threat from development, SLR and 39 increased wave energy during storms and (high confidence) (Sections 3.4.2.6, 3.4.4–3.4.6, 3.5.6, Lithgow et 40 al., 2019; Ruiz-Ramírez et al., 2019). Engineered solutions like seawalls and revetments have traditionally 41 been used to address coastal erosion (Section 3.6.3.1.1), but soft infrastructure approaches, including beach 42 nourishment, submerged breakwaters and groins, and NbS (Section 3.6.2.1), are becoming more common, 43 partly due to demand from the tourism industry (medium confidence) (Pranzini, 2018; Pranzini et al., 2018). | Heritage | 506 - 506 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 44 45 Elsewhere, interactions between tourism and climate impacts worsen outcomes for coastal and ocean 46 environments (Section 3.6.3.1.4). Climate change is opening up new cruise-ship routes in the Arctic (Sun et 47 al., 2018), increasing number of visitors and associated stressors, such as litter, to previously undisturbed 48 areas (Anfuso et al., 2020; Hovelsrud et al., 2020; Suaria et al., 2020). Risk reduction for cruise-ship tourism 49 includes disaster response management, improved mapping, and passenger codes of conduct ensuring social, 50 cultural and ecological sustainability (Stewart et al., 2015; Dawson et al., 2016). | Heritage | 506 - 506 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 5 6 Unintended consequences of ecotourism, such as detrimental ecological impacts on reefs (Giglio et al., 7 2020), sharks, marine birds (Monti et al., 2018), and whales (Higham et al., 2016; Barra et al., 2020; Hoarau 8 et al., 2020), can be minimised by relying on evidence-based management of associated activities (Blumstein 9 et al., 2017). Public perception of climate change connections to tourism can create obstacles (Meynecke et 10 al., 2017; Atzori et al., 2018) such as deterring long-term investment in SIDS tourism initiatives (Santos- 11 Lacueva et al., 2017), or benefits like inclining tourists to participate in conservation projects (Curnock et al., 12 2019; Miller et al., 2020b; Ziegler et al., 2021). Social and cultural networks may decrease climate 13 vulnerability, as with Indigenous tourism operators in SIDS (Parsons et al., 2018). Tourism-based adaptation 14 can also be improved by equitable access to resources, and recognition and inclusion of all stakeholders 15 during policy planning and implementation. The principles of marine spatial planning (Papageorgiou, 2016) 16 provide for effectively incorporating stakeholders and could inform development of activities to assess 17 climate-associated risks (e.g., Tzoraki et al., 2018; Loehr, 2020). The recent decrease in global tourism due 18 to the COVID-19 pandemic may offer opportunities to transform existing practices to more sustainable 19 approaches (Cross-Chapter Box COVID in Chapter 7, Gössling et al., 2021). | Heritage | 507 - 507 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 20 21 3.6.3.1.4 Maritime transport 22 Increased maritime transport and cruise-ship tourism in the Arctic are already impacting local and 23 Indigenous Peoples, revealing conflicts over the uses of the ocean and the governance needed to support 24 local people and a sustainable blue economy (high confidence) (Debortoli et al., 2019; Palma et al., 2019; 25 Berman et al., 2020; Dundas et al., 2020). While shipping and its associated environmental impacts are 26 projected to grow (Palma et al., 2019; Dawson et al., 2020), adaptation efforts are only at the planning stage 27 (Debortoli et al., 2019). Increased Arctic traffic due to ice loss can benefit trade, transportation and tourism 28 (medium confidence), but will also affect Arctic marine ecosystems and livelihoods (high confidence) (Palma 29 et al., 2019; Dawson et al., 2020). Increasing search-and-rescue activities (Ford and Clark, 2019) reveal 30 capacity gaps to support future demands (Ford and Clark, 2019; Palma et al., 2019). The Low-Impact 31 Shipping Corridors initiative has been developed as an adaptation strategy in the Arctic, although with 32 limited inclusion of IK and LK (Dawson et al., 2020). | Heritage | 507 - 507 |

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| IPCC | IPCC_AR6_WGII_Full_Report | 46 47 Models show that a combination of available management approaches (restoration, reducing non-climate 48 drivers) and speculative interventions (enhanced corals, reef shading) can contribute to sustaining some coral 49 reefs beyond 1.5°C of global warming with declining effectiveness beyond 2°C of global warming (medium 50 confidence) (Figure 3.25, WGII Chapter 17). These proposed interventions are also currently theoretical and 51 impractical over large scales; for example, engineered solutions like reef shading are untested and not 52 scalable at the reef level (Condie et al., 2021). Existing projects suggest that restoration and ecological 53 interventions to habitat-forming ecosystems have additional benefits of raising local awareness, promoting 54 tourism, and creating jobs and economic benefits (Fadli et al., 2012; Boström-Einarsson et al., 2020; Hafezi 55 et al., 2021), provided communities are involved in planning, operation and monitoring (Boström-Einarsson 56 et al., 2020). | Heritage | 511 - 511 |
| IPCC | IPCC_AR6_WGII_Full_Report | 24 25 3.6.3.3.1 Sociocultural dimensions (culture, ethics, identity, behaviour) 26 Every coastal community values marine ecosystems for more than the material and intangible resources they 27 deliver, or the physical protection they offer (Díaz et al., 2018). Cultural services that provide identity, 28 spiritual and cultural continuity, religious meaning, or options for the future (e.g., genetic or mineral 29 resources, Bindoff et al., 2019), are not substitutable. Furthermore, interactions between climate impacts and 30 existing inequalities can threaten the human rights of already-marginalised peoples by disrupting livelihoods 31 and food security, which further erodes people's social, economic, and cultural rights (Finkbeiner et al., ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 3 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 3-137 Total pages: 236 1 2018). For instance, European colonisation and ongoing development blocked the Cucapá Indigenous 2 People's access and rights to resources in the Colorado River Delta, USA, over the 20th century. Recent 3 reallocation of water rights and fishing access is allowing the Cucapá people to reconstruct their cultural 4 identity (Sangha et al., 2019), but future climate change impacts could reverse the community's recovery of 5 their cultural heritage. Adaptations that consider local needs may help sustain cultural services (Ortíz Liñán 6 and Vázquez Solís, 2021). | Heritage | 512 - 513 |
| IPCC | IPCC_AR6_WGII_Full_Report | 7 8 Interactions with oceans are fundamental to the identities of many coastal Indigenous Peoples (Norman, 9 2017) and this influences Indigenous responses to climate hazards and adaptation. Around 30 million 10 Indigenous Peoples live along coasts (Cisneros-Montemayor et al., 2016). Seafood consumption among 11 Indigenous Peoples is much higher than for non-Indigenous populations, and marine species support many 12 cultural, medicinal and traditional activities contributing to public health (Section 3.5.3.1, Kenny et al., 13 2018). Perpetuation of Indigenous cultures depends on protecting marine ecosystems and on adapting to 14 changes in self-led ways (see Section 3.5.6, Sangha et al., 2019) that promote self-determination (von der 15 Porten et al., 2019). Indigenous resurgence, or reinvigorating Indigenous ways of life and traditional 16 management, can include marine resource protection and ocean-sector development founded on culturally 17 appropriate strategies and partnerships, that are consistent with traditional norms and beneficial to local 18 communities (von der Porten et al., 2019). Successful adaptation would simultaneously improve ecosystem 19 health and address current and historical inequities (Bennett, 2018). Examples include practicing traditional 20 resource management, protecting traditional territories, engaging with monitoring, collaborations with non- 21 Indigenous partners, and reinvesting benefits into capacity-building within communities (von der Porten et 22 al., 2019; Equator Initiative, 2020). The legitimacy of different adaptation strategies depends on local and 23 Indigenous Peoples' acceptance, which is based on cultural values (Adger et al., 2017); financial gain cannot 24 compensate for loss of IK or LK (Wilson et al., 2020b). Palau's recent goal of shifting seafood consumption 25 away from reef fishes (Remengesau Jr., 2019) and limiting and closely monitoring the expansion of 26 ecotourism was prompted by the cultural importance of protecting these reefs and associated traditional 27 fisheries for local consumption, a recognition of the importance of tourism, and the hazard of climate change 28 (Wabnitz et al., 2018a). | Heritage | 513 - 513 |
| IPCC | IPCC_AR6_WGII_Full_Report | 38 39 Transparency, coherence between different actors and initiatives, and project monitoring and evaluation 40 enhance success in adapting and achieving SDG14 (Life below water) (Blasiak et al., 2019). Maladaptation 41 (WGII Chapter 16, Magnan et al., 2016), is a common risk of current project-based funding due to the 42 pressure to produce concrete results (medium confidence) (Parsons and Nalau, 2019; Nunn et al., 2020; Nunn 43 et al., 2021). Maladaptation can be avoided through a focus on building adaptive capacity, community-based 44 management, drivers of vulnerability and site-specific measures (low confidence) (Magnan and Duvat, 2018; 45 Piggott-McKellar et al., 2020; Schipper, 2020). More research is needed to identify ways that governance 46 and financing agreements can help overcome financial barriers and socio-cultural constraints to avoid 47 maladaptation in coastal ecosystems (high confidence) (Hinkel et al., 2018; Miller et al., 2018; Piggott- 48 McKellar et al., 2020; Schipper, 2020). | Heritage | 514 - 514 |
| IPCC | IPCC_AR6_WGII_Full_Report | 29 Such development could help small nations reliant on imported fuel meet their climate-mitigation goals and 30 decrease risk from global fuel supply dynamics (Millar et al., 2017; Chen et al., 2018a), but progress is 31 limited by lack of investment (Millar et al., 2017; Lee et al., 2020) or equipment (Aderinto and Li, 2018; 32 Rusu and Onea, 2018). Wave-energy installations, possibly co-located with wind turbines(Perez-Collazo et 33 al., 2018), are promising for both low- to middle-income nations and areas with significant island or remote 34 coastal geographies (Lavidas and Venugopal, 2016; Bergillos et al., 2018; Jakimavičius et al., 2018; Kompor 35 et al., 2018; Penalba et al., 2018; Saprykina and Kuznetsov, 2018; Lavidas, 2019). Wave-energy capture may 36 also diminish storm-induced coastal erosion (Abanades et al., 2018; Bergillos et al., 2018). Tidal energy is a 37 relatively new technology (Haslett et al., 2018; Liu et al., 2018; Neill et al., 2018) with limiting siting 38 requirements (Mofor et al., 2013). Ocean renewable energy expansion faces other technological obstacles 39 including lack of implementable or scalable energy-capture devices, access to offshore sites, competing 40 coastal uses, potential environmental impacts, and lack of power-grid infrastructure at the coast (Aderinto 41 and Li, 2018; Neill et al., 2018). | Heritage | 515 - 515 |

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| IPCC | IPCC_AR6_WGII_Full_Report | 6 7 Marine adaptation also shows promise for helping support achievement of economic SDGs (medium 8 confidence) (Figure 3.26). Marine NbS could help blue economy frameworks achieve Decent Work and 9 Economic Growth (SDG8) (Lee et al., 2020), by sustainably and equitably incorporating ecosystem-based 10 fisheries management, restoration or conservation (Sections 3.6.3.1.2, 3.6.3.2.1 and 3.6.3.2.2) (Voyer et al., 11 2018; Cisneros-Montemayor et al., 2019; Cohen et al., 2019; Okafor-Yarwood et al., 2020). NbS that involve 12 active restoration or accommodation can contribute to Sustainable Cities and Communities (SDG11) and 13 Infrastructure (SDG9) (Section 3.6.3.1.1). Newly developed marine industries and livelihoods associated 14 with NbS might support attainment of Sustainable Communities (SDG11) (Cisneros-Montemayor et al., 15 2019). Finance and market mechanisms to support disaster relief or ocean ecosystem services, such as blue 16 carbon or food provisioning, and innovations (SDG9) including new technologies like vessel-monitoring 17 systems (Kroodsma et al., 2018), can contribute to Responsible Consumption and Production (SDG12) 18 (Sumaila and Tai, 2020). Blue economy growth that includes sustainable shipping, tourism, renewable ocean 19 energy, and transboundary fisheries management (Pinsky et al., 2018) have the potential to contribute to 20 Economic Development (SDG8), affordable and clean energy (SDG7) (as well as global mitigation efforts, 21 SDG13, (Hoegh-Guldberg et al., 2019b; Duarte et al., 2020)). Participatory approaches and co-management 22 systems (Section 3.6.2.1) in many maritime sectors can contribute to SDG11 and SDG12 while helping align 23 the blue economy and the SDGs (high agreement) (Lee et al., 2020; Okafor-Yarwood et al., 2020). | Heritage | 517 - 517 |
| IPCC | IPCC_AR6_WGII_Full_Report | 19 Ambitious and swift global mitigation offers more adaptation options and pathways to sustain ecosystems 20 and their services (Figure 3.25). Some solutions target both mitigation and adaptation (e.g., blue carbon 21 conservation, Cross-Chapter Box NATURAL in Chapter 2, Box 3.4), and cross-cutting solutions 22 simultaneously support several ocean-related sectors (e.g., area-based measures support fishing, tourism; 23 Section 3.6.3.2.1) or ecosystem functions (e.g., NbS support coastal protection, biodiversity, habitat, etc., 24 Section 3.6.3.2.2, Sala et al., 2021). Combined solutions also leverage a variety of existing policies and 25 governance systems (Section 3.6.4.3, Duarte et al., 2020) to advance climate mitigation and adaptation. Even 26 communities that face the limits of adaptation, like those who must relocate to cope with rising seas 27 (McMichael et al., 2019; Bronen et al., 2020), urgently require solutions that combine scientific projections, 28 IK and LK, cultural and community values, and ways to preserve cultural identity to support planning and 29 implementation of relocation (McMichael and Katonivualiku, 2020). | Heritage | 519 - 519 |
| IPCC | IPCC_AR6_WGII_Full_Report | 4 5 Human communities can also experience tipping points that alter people’s relationships with marine 6 ecosystem services. Indigenous Peoples and local communities may be forced to move from a particular 7 location due to sea-level rise, erosion, or loss of marine resources. Current activities that help sustain 8 Indigenous Peoples and their cultures may no longer be possible in the coming decades, and traditional diets 9 or territories may have to be abandoned. These tipping points have implications for physical and mental 10 health of marine-dependent human communities. | Heritage | 521 - 521 |
| IPCC | IPCC_AR6_WGII_Full_Report | 14 Examples include diversifying income by shifting from fishing to tourism and relocating communities 15 threatened by flooding to other areas to continue their livelihoods. Tipping points are being passed already in 16 coral reefs and polar systems, and more will probably be reached in the near future, given climate-change 17 projections. Nevertheless, the chances of moving beyond additional tipping points in the future will be 18 minimised if we reduce greenhouse gas emissions, and we also act to limit other human impacts on the 19 ocean, such as overfishing and nutrient pollution. | Heritage | 521 - 521 |
| IPCC | IPCC_AR6_WGII_Full_Report | 5 6 The projected ecological impacts of MHWs threaten local communities’ and Indigenous Peoples’ cultures, 7 incomes, fisheries, tourism, and, in the case of coral reefs, shoreline protection from waves. High-resolution 8 forecasts and early-warning systems, currently most advanced for coral reefs, can help people and industries 9 prepare for MHWs and also collect data on their effects. Identifying and protecting locations and habitats 10 with reduced exposure to MHWs is a key scientific endeavour. For example, corals may be protected from 11 MHWs in tidally-stirred waters or in reefs where cooler water upwells from subsurface. Marine protected 12 areas and no-take zones, in addition to terrestrial protection surrounding vulnerable coastal ecosystems, 13 cannot prevent MHWs from occurring. But, depending on the location and adherence by people to 14 restrictions on certain activities, the cumulative effect of other stressors on vulnerable ecosystems can be 15 reduced, potentially helping to enhance the rate of recovery of marine life. | Heritage | 523 - 523 |
| IPCC | IPCC_AR6_WGII_Full_Report | 3 4 The global ocean underpins human well-being through the provision of resources that directly and indirectly 5 feed and employ many millions of people. In many regions, climate change is degrading ocean health and 6 altering stocks of marine resources. Together with over-harvesting, climate change is threatening the future 7 of the sustenance provided to Indigenous Peoples, the livelihoods of artisanal fisheries, and marine-based 8 industries including tourism, shipping and transportation. | Heritage | 524 - 524 |
| IPCC | IPCC_AR6_WGII_Full_Report | 33 Declines in tourism and real estate values have also been recorded in the United States, France, and England 34 associated with climate-driven harmful algal blooms. | Heritage | 524 - 524 |
| IPCC | IPCC_AR6_WGII_Full_Report | 44 45 Jobs, industries and livelihoods which depend on particular species or are tied to the coast can also be at risk 46 to climate change. Species-dependent livelihoods (e.g., a lobster fishery or oyster farm) are vulnerable due to 47 a lack of substitutes if the fished species are declining, biodiversity is reduced, or mariculture is threatened 48 by climate change or ocean acidification. Coastal activities and industries ranging from fishing (e.g., 49 gleaning on a tidal flat) to tourism to shipping and transportation are also vulnerable to sea-level rise and 50 other climate-change impacts on the coastal environment. The ability of coastal systems to protect the 51 shoreline will decline due to sea-level rise and simultaneous degradation of nearshore systems including 52 coral reefs, kelp forests and coastal wetlands. | Heritage | 524 - 524 |

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| IPCC | IPCC_AR6_WGII_Full_Report | 53 54 The vulnerability of communities to losses in marine ecosystem services varies within and among 55 communities. Tourists seeking to replace lost cultural services can adapt by engaging in the activity 56 elsewhere. But communities who depend on tourism for income or who have strong cultural identity linked 57 to the ocean have a more difficult time. Furthermore, climate-change impacts exacerbate existing inequalities ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 3 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 3-149 Total pages: 236 1 already experienced by some communities, including Indigenous Peoples, Pacific Island countries and 2 territories, and marginalized peoples, like migrants and women in fisheries and mariculture. These inequities 3 increase the risk to their fundamental human rights by disrupting livelihoods and food security, while leading 4 to loss of social, economic, and cultural rights. These maladaptive outcomes can be avoided by securing 5 tenure and access rights to resources and territories for all people depending on the ocean, and by supporting 6 decision-making processes that are just, participatory and equitable. | Heritage | 524 - 525 |
| IPCC | IPCC_AR6_WGII_Full_Report | 20 Coastal habitats like mangroves or vegetated dunes protect coastal communities from sea-level rise and 21 storm surges, while supporting fisheries, recreational and aesthetic services as well. Seagrasses, coral reefs 22 and kelp forests also provide important benefits that help humans adapt to climate change, including 23 sustainable fishing, recreation and shoreline protection services. By recognizing these services and benefits 24 of the ocean, nature-based solutions can improve the quality and integrity of the marine ecosystems. | Heritage | 526 - 526 |
| IPCC | IPCC_AR6_WGII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 3 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 3-151 Total pages: 236 1 2 3 Figure FAQ3.5: Contributions of nature-based solutions in the oceans to the Sustainable Development Goals. The 4 icons in the bottom show the Sustainable Development Goals to which nature-based solutions in the ocean possibly 5 contribute. [Placeholder figure -- authoritative version on FMS] 6 7 8 [END FAQ3.5 HERE] 9 10 11 Acknowledgements 12 We acknowledge the kind contributions of Rita Erven (GEOMAR Helmholtz Centre for Ocean Research 13 Kiel, Germany), Miriam Seifert (Alfred Wegener Institute for Polar and Marine Research, Germany), 14 Sebastian Rokitta (Alfred Wegener Institute for Polar and Marine Research, Germany), Amy Marie 15 Campbell (National Oceanography Centre, Southampton/Centre for Environment, Fisheries and Aquaculture 16 Science, United Kingdom), Mariana Castaneda-Guzman (Virginia Polytechnic Institute and State University, 17 USA), Stephen Goult (Plymouth Marine Laboratory/National Centre for Earth Observation, United 18 Kingdom), Josh Douglas (Plymouth Marine Laboratory, United Kingdom), Carl Reddin (Museum für 19 Naturkunde, Berlin, Germany) and the PML Communications and Graphics Team (Plymouth Marine 20 Laboratory, United Kingdom) who assisted in drafting figures and tables. | Heritage | 526 - 527 |
| IPCC | IPCC_AR6_WGII_Full_Report | 59 Anzidei, M. et al., 2020: Sea Level Rise Scenario for 2100 A.D. in the Heritage Site of Pyrgi (Santa Severa, Italy). | Heritage | 529 - 529 |
| IPCC | IPCC_AR6_WGII_Full_Report | 27 28 In summary, global mean soil moisture has slightly decreased, but regional changes vary, with both increases 29 and decreases of 20% or more in some regions (medium confidence). Drying soil moisture trends are more 30 widespread than wetting trends, not only in arid areas but also in humid and transitional areas (medium 31 confidence). Reduced dry-season water availability is driven mainly by increasing transpiration (medium 32 confidence) 33 34 4.2.2 Observed Changes in Cryosphere (Snow, Glaciers, and Permafrost) 35 36 AR5 reported a decrease in snow cover over most of the Northern Hemisphere, decreases in the extent of 37 permafrost and increases in its average temperature, and glacier mass loss in most parts of the world 38 (Jiménez Cisneros et al., 2014). SROCC (IPCC, 2019c) stated with very high or high confidence (a) 39 reduction in seasonal snow cover (snow cover extent decreased by 13.4% per decade for 1967-2018); (b) 40 glacier mass budget of all mountain regions (excluding the Canadian and Russian Arctic, Svalbard, Antarctica, Greenland) was 490±100 kg m-2 yr-1 41 in 2006-2015; (c) warming of permafrost (e.g. permafrost 42 temperatures increased by 0.39°C in the Arctic for 2007-2017). Tourism and recreation activities have been 43 negatively impacted by declining snow cover, glaciers and permafrost in high mountains (medium 44 confidence). | Heritage | 634 - 634 |
| IPCC | IPCC_AR6_WGII_Full_Report | 25 26 27 Regional and global decreasing trends in glacier mass loss are about linear until 1990, after which they 28 accelerated, especially in Western Canada, the USA, and Southern Andes (WGMS, 2017). There is a ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 4 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 4-24 Total pages: 213 1 worldwide growth in the number, total area and total volume of glacial lakes by around 50% between 1990 2 to 2018 due to the global increase in glacier melt rate (Shugar et al., 2020). An increase in area, number and 3 volume of glacial lakes can potentially increase risks of GLOFs with significant negative societal impacts 4 (Ikeda et al., 2016). A drop in glacier runoff has happened in the regions where the glaciers have already 5 passed their peak water stage, example, as in Canadian Rocky Mountains, European Alps, tropical Andes, 6 North Caucasus (Bard et al., 2015; Hock et al., 2019b; Rets et al., 2020). There is medium confidence that the 7 accelerated melting of glaciers has negatively impacted glacier-supported irrigation systems worldwide 8 (Buytaert et al., 2017; Nüsser and Schmidt, 2017; Xenarios et al., 2019). Varying impacts on hydropower 9 production (Schaefli et al., 2019) and tourism industry in some places due to cryosphere changes have also 10 been documented (Hoy et al., 2016; Steiger et al., 2019). | Heritage | 635 - 636 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 40 41 Floods intensify the mixing of floodwater with wastewater and the redistribution of pollutants (Andrade et 42 al., 2018). In addition, contaminated floodwaters pose an immediate health risk through waterborne diseases 43 (Huang et al., 2016b; Paterson et al., 2018; Setty et al., 2018). Wildfires, along with heavy rainfalls and 44 floods, can also affect turbidity, which increases drinking water treatment challenges and has been linked to 45 increases in gastrointestinal illness (de Roos et al., 2017. Droughts reduce river dilution capacities and 46 groundwater levels {Wen, 2017 #2093), increasing the risk of groundwater contamination (Kløve et al., 47 2014). More generally, contaminated water diminishes its aesthetic value, compromising recreational 48 activities, reducing tourism and property values, and creating challenges for management and drinking water 49 treatment (Eves and Wilkinson, 2014; Khan et al., 2015; Walters et al., 2015). | Heritage | 651 - 651 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 40 41 With 1,308 GW installed capacity in 2019, hydropower became the world's largest single source of 42 renewable energy (IHA, 2020) (also see Figure 6.12, WGIII). While hydropower reduces emissions relative 43 to fossil fuel-based energy production, hydropower reservoirs are being increasingly associated with GHG 44 emissions caused by submergence and later re-emergence of vegetation under reservoirs due to water level 45 fluctuations (Räsänen et al., 2018; Song et al., 2018; Maavara et al., 2020). A recent global study concluded 46 that reservoirs might emit more carbon than they bury, especially in the tropics (Keller et al., 2021) (medium 47 confidence). | Heritage | 655 - 655 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 16 17 Case 7. Improved preparedness reduced mortality: Heatwave in Europe, 2019 18 19 In 2019, Europe experienced several record-breaking heatwaves. In June, the first one featured record heat 20 for that time in early summer, with temperatures of 6-10°C above normal over most of France and Germany, 21 northern Spain, northern Italy, Switzerland, Austria, and the Czech Republic (Climate., 2019). The second 22 heatwave also resulted in all-time records for Belgium, Germany, Luxembourg, the Netherlands, and the 23 United Kingdom in July. Attribution studies (Vautard et al., 2020) demonstrated that these would have had 24 extremely small odds in the absence of human-induced climate change or would have been 1.5-3°C colder 25 without human-induced climate change. This study concluded that state-of-the-art climate models 26 underestimate the trends in local heat extremes compared to the observed trend. Since the 2003 heatwave, 27 which resulted in tens of thousands of deaths across Europe, many European countries have adopted 28 heatwave plans, including early warning systems. Therefore, mortality in 2019 was substantially lower than 29 it might have been. Unfortunately, mortality is not registered systematically across Europe, and therefore 30 comprehensive analyses are missing. But even based on the countries that provide the numbers, more 31 specifically France, Belgium and the Netherlands, the European heatwave of 2019 resulted in over 2500 32 deaths (CRED, 2019). Despite their deadliness and the fact that climate change increases the frequency, 33 intensity and duration of heatwaves globally (Perkins-Kirkpatrick and Lewis, 2020) , heatwaves are not 34 consistently reported in many countries (Harrington and Otto, 2020), rendering it currently impossible to 35 estimate climate change impacts on lives and livelihoods comprehensively. | Heritage | 661 - 661 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 23 24 Temperature changes lead to changes in the distribution patterns of freshwater species. Poleward and up- 25 elevation range shifts due to warming temperatures tend to ultimately lead to reduced range sizes. Freshwater 26 species in the tropics are particularly vulnerable (Jezkova and Wiens, 2016; Sheldon, 2019). Systematic 27 shifts towards higher elevation and upstream were found for 32 stream fish species in France (Comte and 28 Grenouillet, 2013). In North America, for the bull trout (Salvelinus confluentus) a reduction in the number of 29 occupied sites was documented in a watershed in Montana (Eby et al., 2014). Other impacts include 30 disruption of seasonal movements of migratory waterbirds that regularly visit freshwater ecosystems, with 31 adverse impacts on their feeding and breeding (Finlayson et al., 2006; Bussière et al., 2015). Keystone 32 species, such as the beaver (Caster Canadensis) in North America, have been moving into new areas as the 33 vegetation structure has changed in response to higher temperatures enabling shrubs to establish in the Arctic 34 and alpine tundra ecosystems (Jung et al., 2016). Increased occurrence and intensity of algal blooms have 35 occurred due to the interactive effects of thermal extremes and low dissolved oxygen concentrations in water 36 (Griffith and Gobler, 2020) (4.2.7). A global review found that almost 90% of all studies reviewed 37 documented a decline in salmonid populations in North Amercia and Europe, and identified knowledge gaps 38 elsewhere (Myers et al., 2017). Another review (Pecl et al., 2017) found declines in Atlantic salmon in 39 Finland, and poleward shift in coastal fish species, while another review (Scheffers et al., 2016) noted 40 hybridization between freshwater species like invasive rainbow trout (Oncorhynchus mykiss) and native 41 cutthroat trout (O. clarkia). | Heritage | 664 - 664 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 57 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 4 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 4-55 Total pages: 213 1 Freshwater (including ice and snow) has diverse meanings and symbolic representations, as well as 2 associated practices, management and reciprocal responsibilities for many Indigenous Peoples, local 3 communities and traditional peoples (Cave and McKay, 2016; Craft, 2018; Hansen and Antsanen, 2018; 4 Ngata, 2018; Chiblow 2019; Wilson et al., 2019; Moggridge and Thompson, 2021). Climate-driven 5 hydrological changes are affecting culturally significant terrestrial and freshwater species and ecosystems, 6 particularly for Indigenous Peoples, local communities and traditional peoples in the Arctic, high-mountain 7 areas, and small islands (high confidence). These climate impacts on cultural water uses are influencing 8 travel, hunting, herding, fishing, and gathering practices, which have negative implications for livelihoods, 9 cultural traditions, economies, and self-determination (Table 4.5). | Heritage | 666 - 667 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 10 11 Some of these losses may be classified as non-economic loss and damage, such as loss of culture and 12 traditions (Thomas and Benjamin, 2018b; McNamara et al., 2021). The vulnerability of these cultural uses to 13 climate change is exacerbated by historical and ongoing processes of colonialism and capitalism, which 14 dispossessed Indigenous Peoples and disrupted culturally significant multi-species relationships (Whyte, 15 2017; Whyte, 2018; Wilson et al., 2019; Whyte, 2020; Rice et al., 2021) (14.4.7.3; 9.13.2.4). Despite these 16 significant structural barriers, there is medium confidence that some Indigenous Peoples, local communities 17 and traditional peoples are adapting to the risks of climate-driven hydrological changes to cultural water uses 18 and practices (4.6.9). | Heritage | 667 - 667 |
| IPCC | IPCC_AR6_WGII_Full_ Report | Rainy summers increase the difficulty of gathering and moving reindeer to round-up sites and limit hay production for supplementary winter feed (13.8.1.2). | Heritage | 669 - 669 |
| IPCC | IPCC_AR6_WGII_Full_ Report | (Albert et al., 2018); (Norton�Smith et al., 2016) Small Islands iTaukei Sea level rise Flooding, inundation and salt�water intrusion The village of Vunidogola was relocated in response to inundation, storm surges and flooding, which villagers found emotionally and spiritually distressing. Although the village was relocated as a single unit and on customary lands, the shift away from the coast has impacted spiritual relationships, as the ocean is an integral part of village culture (15.6.5). | Heritage | 669 - 669 |
| IPCC | IPCC_AR6_WGII_Full_ Report | (Charan et al., 2017); (Piggott�McKellar et al., 2019a) ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 4 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 4-58 Total pages: 213 Small Islands iTaukei Sea level rise Coastal erosion; inundation Villagers of Viti Levu reported their grief at the potential loss of their traditions and livelihoods. In addition, they are concerned as to how climate change is affecting their cosmology and cultural traditions and understand possible relocation as another source of cultural loss (15.6.5). | Heritage | 669 - 670 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 28 29 Apart from climate impacts on hydropower production, climate-induced flood loads and reservoir water level 30 change may lead to dam failure under RCP2.6 and RCP4.5 scenarios (Fluixá-Sanmartín et al., 2018; Fluixá- 31 Sanmartín et al., 2019) (medium confidence). For example, the incidence of 100-year floods in the Skagit 32 river basin in the US and peak winter sediments are projected to increase by 49% and 335%, respectively, by 33 2080, necessitating fundamental changes in hydropower plant operation. Nevertheless, some risks, such as 34 floods, will remain unmitigated even with changes in hydropower operation rules (Lee et al., 2016). Overall, 35 impacts of future extreme events on energy infrastructure have been less studied than impacts of gradual 36 changes (Cronin et al., 2018). Furthermore, future hydropower development may also impact areas of high 37 freshwater megafauna in South America, South and East Asia, and in the Balkan region, and sub-catchments 38 with a high share of threatened freshwater species are particularly vulnerable (Zarfl et al., 2019). Therefore, 39 future hydropower dams will need to be sited carefully (Dorber et al., 2020). | Heritage | 693 - 693 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 54 55 4.5.8 Projected Risks to the Cultural Water Uses of Indigenous Peoples, Local Communities and 56 Traditional Peoples 57 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 4 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 4-87 Total pages: 213 1 AR5 found that climate change will threaten cultural practices and values, although the risks vary across 2 societies and over time (medium evidence, high agreement). Furthermore, AR5 concluded that significant 3 changes in the natural resource base on which many cultures depend would directly affect the cultural core, 4 worldviews, cosmologies and symbols of Indigenous cultures (Adger and Pulhin, 2014). SR1.5 concluded 5 with high confidence that limiting global warming to 1.5°C, rather than 2°C, will strongly benefit terrestrial 6 and wetland ecosystems and their services, including the cultural services provided by these ecosystems 7 (Hoegh-Guldberg et al., 2018). SROCC found with high confidence that cultural assets are projected to be 8 negatively affected by future cryospheric and associated hydrological changes (Hock et al., 2019b). | Heritage | 698 - 699 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 9 10 There is high confidence that the cultural water uses of Indigenous Peoples, local communities, and 11 traditional peoples are at risk of climate change-related hydrological change (Table 4.7). Climate-driven 12 variations in streamflow, saltwater intrusion, and projected increases in water temperature will exacerbate 13 declines of culturally important species and lead to variations or depletion of culturally important places and 14 subsistence practices. For example, in New Zealand, the increasing risk of flood events may impact 15 culturally important fish species for Māori (Carter, 2019), while habitat changes may shift the distribution of 16 culturally significant plants (Bond et al., 2019). In Australia, Yuibera and Koinmerburra Traditional Owners 17 fear the saltwater inundation of culturally significant sites and waterholes (Lyons et al., 2019), while the 18 flooding of culturally significant wetlands will negatively affect the Lumbee Tribe (USA) (Emanuel, 2018). | Heritage | 699 - 699 |
| IPCC | IPCC_AR6_WGII_Full_ Report | (Soriano and Herath, 2020) Australasia Yuibera and Koinmerburra Traditional Owner groups Sea level rise Flooding Culturally important coastal waterholes, wetlands and sites are at risk of saltwater inundation due to rising sea levels. If inundated, traditional owners may not be able to maintain cultural connections to these important sites (11.4.1). | Heritage | 699 - 699 |
| IPCC | IPCC_AR6_WGII_Full_ Report | Lyons, 2019 #2810} Australasia Māori Increased precipitation Flooding Increasing flood events may negatively impact spawning and fishing sites of the culturally important īnaka (whitebait; Galaxias maculates) in the Waikōuaiti River (11.4.2). | Heritage | 699 - 699 |

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| Organisation | Document | Quotation Content | Codes | Page |
|---|---|---|---|---|
| IPCC | IPCC_AR6_WGII_Full_Report | Central and South America Warao Sea level rise Flooding The partial or total inundation of the Orinoco Delta will result in the loss of freshwater wetlands and species, which will produce rapid shifts in the culturally significant lands and resources of the Warao. Among the affected species is the Mauritia palm, on which Warao culture and livelihoods are based. | Heritage | 700 - 700 |
| IPCC | IPCC_AR6_WGII_Full_Report | (Vegas�Vilarrúbia et al., 2015) Europe Saami Increased temperatures; changes in precipitation Winter thaw Reindeer herding is culturally important for Saami and provides a means to maintain traditions, language and cultural identity, thus constituting an essential part of Saami physical and mental wellbeing. | Heritage | 700 - 700 |
| IPCC | IPCC_AR6_WGII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 4 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 4-101 Total pages: 213 1 2 3 In most regions, hybrid adaptation approaches are underway. For example, sustainable urban drainage 4 systems (SUDS) are a common adaptation measure that can reduce flooding and improve stormwater quality 5 while reducing the urban heat island effect (e.g. (Chan et al., 2019; Loiola et al., 2019; Song et al., 2019; 6 Huang et al., 2020; Lin et al., 2020)) (Box 4.6; 12.5.5.3.2; 12.7.1). Municipal, catchment and local 7 community plans to minimise water-related climate risks are another form of adaptation (Stults and Larsen, 8 2018). Plans involve supply augmentation (Chu, 2017; Bekele et al., 2018), as well as floodplain 9 management, land-use planning, stakeholder coordination, and water demand management (Andrew and 10 Sauquet, 2017; Flyen et al., 2018; Robb et al., 2019; Tosun and Leopold, 2019), with some US cities 11 including strategies to address social inequalities that climate change may exacerbate (Chu and Cannon, 12 2021). | Heritage | 712 - 713 |
| IPCC | IPCC_AR6_WGII_Full_Report | 21 22 Further studies are required to ascertain the effectiveness of adaptation measures implemented since AR5, 23 particularly for the growing populations of informal and peri-urban settlements. For example, in urban 24 Africa, such informal settlements are sites of political contestation as residents resist municipal relocation 25 strategies for flood alleviation (Douglas, 2018). In addition, the growing complexity of challenges facing 26 urban water management, such as climate change, urbanisation and environmental degradation, warrants a 27 transformative shift away from prevailing siloed approaches of water supply, sanitation and drainage to more 28 integrated systems that enhance adaptive capacity (Ma et al., 2015; Franco-Torres et al., 2020). | Heritage | 713 - 713 |
| IPCC | IPCC_AR6_WGII_Full_Report | 44 45 There is high confidence that some Indigenous Peoples, local communities, and traditional peoples could and 46 are adapting to climate-driven hydrological changes and their impacts on culturally-significant sites, species, 47 ecosystems, and practices in polar, high mountain and coastal areas, where sufficient funding, decision- 48 making power and resourcing exist (e.g., (Golden et al., 2015; Bunce et al., 2016; Anderson et al., 2018). | Heritage | 717 - 717 |
| IPCC | IPCC_AR6_WGII_Full_Report | 56 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 4 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 4-106 Total pages: 213 1 There is high confidence that local people are adapting to the cultural impacts of climate-driven glacier 2 retreat and decline in snow cover and ice in polar and high mountain areas. However, there is also high 3 confidence that such adaptation can be detrimental and disrupt local cultures. For example, in the Peruvian 4 Andes, concerns about water availability for ritual purposes has led to restrictions on pilgrims' removal of 5 ice and limiting the size of ritual candles to preserve the glacier (Paerregaard, 2013; Allison, 2015). | Heritage | 717 - 718 |
| IPCC | IPCC_AR6_WGII_Full_Report | 6 Relatedly, some local people have questioned the cosmological order, and re-oriented their spiritual 7 relationships accordingly (Paerregaard, 2013; Carey et al., 2017). In Siberia (Mustonen, 2015) and northern 8 Finland (Turunen et al., 2016), community-led decisions among herders favour alternative routing, pasture 9 areas, and shifts in nomadic cycles in response to changing flood events and permafrost conditions (Box 10 13.2). However, loss of grazing land and pasture fragmentation pose adaptation limits, and some strategies 11 such as supplementary feeding and new technologies may further affect cultural traditions of herding 12 communities (Risvoll and Hovelsrud, 2016; Jaakkola et al., 2018). | Heritage | 718 - 718 |
| IPCC | IPCC_AR6_WGII_Full_Report | 16 17 Not all adaptation responses reduce risks, and some may have long term maladaptive outcomes, even if they 18 are beneficial in the short term. Maladaptation often stems from poor planning and implementation of 19 adaptation responses and because of not addressing the root causes of vulnerability (Schipper, 2020; Eriksen 20 et al., 2021). Of the 319 case studies where adaptation response was found to have some beneficial outcomes, around 1/3rd 21 of them also mentioned the possibility of maladaptation. Migration can often have 22 maladaptive outcomes because migration can exacerbate the inherent vulnerabilities of migrants (4.6.8). For 23 example, slum dwellers in cities may earn higher incomes, but their quality of life worsens (Ayeb-Karlsson 24 et al., 2016). In some instances, even wage rates in migration hotspots can remain low due to the high 25 volume of the migrant population (Fenton et al., 2017b); as such, it does not help buffer consumption against 26 rainfall shocks (Gao and Mills, 2018). Migration also has gendered impacts, with girls from migrating 27 families being taken out of school (Gioli et al., 2014) or interrupting children's education overall (Warner 28 and Afifi, 2014). In planned relocation from vulnerable urban slums, relocation sites can be far from job sites 29 and increase social conflicts (Tauhid and Zawani, 2018). | Heritage | 731 - 731 |

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| Organisation | Document | Quotation Content | Codes | Page |
|---|---|---|---|---|
| IPCC | IPCC_AR6_WGII_Full_Report | 45 46 Community-led actions and restoration measures are helping to ameliorate climate impacts and provide "safe 47 havens" to affected freshwater species (high confidence). For example, the Skolt Sámi of Finland have 48 introduced adaptation measures to aid survival of culturally-significant Atlantic salmon stocks in the 49 Näätämö watershed. Atlantic salmon had declined as northern pike, which preys on juvenile salmon, 50 expanded its range in response to warmer water temperatures. Indigenous co-management measures included 51 increasing the catch of pike and documenting important sites (such as lost spawning beds) to ensure 52 ecological restoration encourages further habitat and increased salmon reproduction (Pecl et al., 2017; 53 Mustonen and Feodoroff, 2018). | Heritage | 748 - 748 |
| IPCC | IPCC_AR6_WGII_Full_Report | 21 22 In summary, IK and LK are dynamic and have developed over time to adapt to climate and environmental 23 change in culturally specific and place-based ways (high confidence). Ethical co-production between holders 24 of IK and LK and technical knowledge is a key enabling condition for successful adaptation measures and 25 strategies pertaining to water security, as well as other areas (medium evidence, high agreement). Knowledge 26 co-production is a vital and developing approach to the water-related impacts of climate change that 27 recognises the culture, agency and concerns of Indigenous Peoples and local communities. It is critical to 28 developing effective, equitable and meaningful strategies for addressing the water-related impacts of global 29 warming (Cross-Chapter Box INDIG in Chapter 18). | Heritage | 749 - 749 |
| IPCC | IPCC_AR6_WGII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 5 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 5-5 Total pages: 286 1 in major food-producing regions (medium confidence). {WGI Section 11.8, 5.2.2, 5.4.1, 5.4.3, 5.5.2, 5.5.3, 2 Cross-Chapter Box MOVING PLATE in Chapter 5 this Chapter, Section 5.12.4} 3 4 Impacts on food availability and nutritional quality will increase the number of people at risk of 5 hunger, malnutrition and diet-related mortality (high confidence). Climate change will increase the 6 number of people at risk of hunger in mid-century, concentrated in Sub-Saharan Africa, South Asia and 7 Central America (high confidence) (e.g. between 8 million under SSP1-6.0 to 80 million people under SSP3- 8 6.0). Increased $CO_2$ concentrations will reduce nutrient density in some crops (high confidence). Climate change will increase loss of years of full health3 9 by 10% in 2050 under RCP8.5 due to undernutrition and 10 micronutrient deficiencies (medium evidence, high agreement). {5.2.2, 5.4.2, 5.4.3, 5.12.1.2, 5.12.4; Cross- 11 Chapter Box MOVING PLATE this Chapter} 12 13 Climate change will increasingly expose outdoor workers and animals to heat stress, reducing labour 14 capacity, animal health, and dairy and meat production (high confidence). The number of days with 15 climatically stressful conditions for outdoor workers will increase by up to 250 workdays per year by 16 century's end in some parts of South Asia, tropical sub-Saharan Africa and parts of Central and South 17 America under SSP5-8.5, with negative consequences such as reduced food productivity, higher costs and 18 prices (medium confidence). From early-to end-century, cattle, sheep, goats, pigs and poultry in the low 19 latitudes will face 72-136 additional days per year of extreme stress from high heat and humidity under 20 SSP5-8.5. Meat and milk productivity will be reduced (medium confidence). {5.5.3.4; 5.12.4} 21 22 Climate change will further increase pressures on terrestrial ecosystem services supporting global food 23 systems (high confidence). Climate change will reduce the effectiveness of pollinator agents as species are 24 lost from certain areas, or the coordination of pollinator activity and flower receptiveness is disrupted in 25 some regions (high confidence). Greenhouse gas emissions will negatively impact air, soil, and water quality, 26 exacerbating direct climatic impacts on yields (high confidence). {5.4.3, Box5.3, Box5.4, 5.5.3.4; 5.7.1, 27 5.7.4, 5.10.3} 28 29 Climate change will significantly alter aquatic food provisioning services and water security with 30 regional variances (high confidence). Climate change will reduce marine fisheries and aquaculture 31 productivity, altering the species that will be fished or cultured, and reducing aquaculture habitat in tropical 32 and sub-tropical areas (high confidence).. Global ocean animal biomass will decrease by 5 to 17% under 33 RCP2.6 and 8.5 respectively from 1970 to 2100 with an average decline of 5% for every 1°C of warming, 34 affecting food provisioning, revenue value and distribution, (medium confidence). Global marine aquaculture 35 will decline under warming and acidification from 2020 to 2100, with potential short-term gains for 36 temperate finfish and overall negative impacts on bivalve aquaculture from habitat reduction (50-100% for 37 some countries in the Northern Hemisphere) (medium confidence). Changes in precipitation, sea level, 38 temperature, and extreme climate events will affect food provisioning from inland and coastal aquatic 39 systems (high confidence). Sea-level rise and altered precipitation will increase coastal inundation and water 40 conflicts between water-dependent sectors, such as rice production, direct human use, and hydropower 41 (medium confidence). {5.8.3, 5.9.3, 5.13, Cross-Chapter Box SLR in Chapter 3}. | Heritage | 829 - 830 |
| IPCC | IPCC_AR6_WGII_Full_Report | 26 27 The 1.5°C Special Report concluded that climate-related risks to food security will rise under 1.5°C and will 28 increase further under 2°C or higher. Above 1.5°C, currently available adaptation options will be much less 29 effective and site-specific limits to adaptation will be reached for vulnerable regions and sectors. There was 30 high confidence that limiting warming to 1.5°C will result in smaller net reductions in yields of major crops 31 affecting food availability and nutrition, and that rising temperatures will adversely affect livestock via 32 changes in feed quality, fertility, production, spread of diseases and water availability. | Heritage | 833 - 833 |
| IPCC | IPCC_AR6_WGII_Full_Report | Adaptation projections; food security projections; livelihood projections: e.g. GFPM {TREE} FUND 3.8, DICE 2010, IMPACT {FOOD} ( ) Household and village models Use detailed site-specific data to generate rules that describe the current behaviour of stakeholders such as households or villages. | Heritage | 844 - 844 |

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| Organisation | Document | Quotation Content | Codes | Page |
|---|---|---|---|---|
| IPCC | IPCC_AR6_WGII_Full_ Report | 24 25 5.4.2.2 Inequalities in cropping systems- other crops and regional disparities 26 27 While those working with major crops have benefited from the release of new cultivars, those growing other 28 crops are typically reliant on a heritage cultivars or landraces. While Indigenous knowledge and local 29 smallholder knowledge and practices play an important role in supporting agrobiodiversity which provides 30 genetic diversity resistant to climate-related stresses, a global and national focus in international research, 31 subsidies and support for a few crop species has contributed to an overall decline in agrobiodiversity (FAO, 32 2019e; Song et al., 2019) Similarly, there is a lack of agronomic innovation and research to service ‘minor’ 33 crops (Moriondo et al., 2015; Manners and van Etten, 2018). Even some high value commodities grown 34 outside high-income countries suffer from imbalances in the focus of available credit, research, and 35 innovation (Section 5.4.4.3; Glover, 2014; Fischer, 2016; Farrell et al., 2018). There is a possibility that a 36 lack of adaptive capacity and policy support will drive these growers to move away from these diverse crops, ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 5 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 5-29 Total pages: 286 1 further reducing the resilience of food systems by increasing risk of crop loss from pests, disease and drought 2 and potential loss of Indigenous or local knowledge (Section 5.13.5, Table Box 5.1.1). In the Andean 3 Altiplano of Bolivia, for example, Indigenous farmers have traditionally managed a diverse set of native 4 crops which are drought and frost-tolerant, using cultural practices of seed selection and exchange, but have 5 faced an increase in pests and diseases and a decline of traditional crops due to climate change related 6 stresses, out-migration and intensification drivers (Meldrum et al., 2018). | Heritage | 853 - 854 |
| IPCC | IPCC_AR6_WGII_Full_ Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 5 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 5-35 Total pages: 286 1 2 Temperature is the primary determinant for vine development. Recent warming trends have advanced 3 flowering, maturity, and harvest (high confidence) (Koufos et al., 2014; Cook and Wolkovich, 2016; Hall et 4 al., 2016; Ruml et al., 2016; van Leeuwen and Destrac-Irvine, 2017; Koufos et al., 2020; Wang et al., 2020b; 5 Wang and Li, 2020), and wine growing regions have expanded outside the normal temperature bounds of 6 locally grown varieties (limited evidence, high agreement) (Kryza et al., 2015; Irimia et al., 2018). Milder 7 winters have affected harvest in ice-wine growing regions (Pickering et al., 2015). Higher temperatures have 8 mixed effects depending on site, but generally decreases grape quality (Barnuud et al., 2014; Morales et al., 9 2014; Sweetman et al., 2014; Kizildeniz et al., 2015; Kizildeniz et al., 2018). Warming increases sugar 10 accumulation and decreases acidity (Leolini et al., 2019). Secondary metabolites are negatively affected 11 (Biasi et al., 2019; Teslić et al., 2019). Developmental phases are projected to proceed faster in response to 12 warming (high confidence) (Fraga et al., 2016a; Fraga et al., 2016b; García de Cortázar-Atauri et al., 2017; 13 Costa et al., 2019; Molitor and Junk, 2019; Sánchez, 2019). However extreme high temperatures may have 14 inhibitory effects on development (Cuccia et al., 2014). | Heritage | 859 - 860 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 31 32 Suitability responses to warming are region-specific. In regions where low temperature is a limiting factor, 33 warming will enable growers to grow a wider range of varieties and obtain better-quality wines (high 34 confidence) (Fuhrer et al., 2014; Mosedale et al., 2015; Mosedale et al., 2016; Meier et al., 2018; Jobin 35 Poirier et al., 2019; Maciejczak and Mikiciuk, 2019). Subtropical and Mediterranean regions will experience 36 major declines in fruit quality for high-quality wines (high confidence) (Resco et al., 2016; Lazoglou et al., 37 2018; Cardell et al., 2019; Fraga et al., 2019a; Fraga et al., 2019b; Teslić et al., 2019). These changes will 38 also affect wine tourism (Nunes and Loureiro, 2016). | Heritage | 860 - 860 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 32 33 [END BOX 5.3 HERE] 34 35 36 5.4.3.4 Observed and projected impacts on cultural ecosystem service 37 38 Cultural ecosystem services (CES) are those non-material benefits, such as aesthetic experiences, recreation, 39 spiritual enrichment, social relations, cultural identity, knowledge and other values (Millennium Ecosystem 40 Assessment, 2005), which support physical and mental health and human well-being (Chan et al., 2012; 41 Triguero-Mas et al., 2015). CES in agricultural and wild landscapes include recreational activities, access to 42 wild or cultivated products, and cultural foods, spiritual rituals, heritage and memory dimensions, and 43 aesthetic experiences (Daugstad et al., 2006; Calvet-Mir et al., 2012; Ruoso et al., 2015). Relative to other 44 ecosystem services, CES in agricultural landscapes has had less research (Merlín-Uribe et al., 2012; Milcu et 45 al., 2013; Bernues et al., 2014; Plieninger et al., 2014; van Berkel and Verburg, 2014; Ruoso et al., 2015; 46 Quintas-Soriano et al., 2016). Agricultural heritage is a key aspect of CES and plays an important role in 47 maintaining agrobiodiversity (Hanaček and Rodríguez-Labajos, 2018). | Heritage | 861 - 861 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 48 49 Climate change is projected to have negative impacts on Cultural ecosystem services (medium confidence) 50 (Table 5.4). There is limited evidence that climate change has been the main driver affecting CES of 51 agroecosystems confounded by other drivers such as migration and changing farming patterns (Hanaček and 52 Rodríguez-Labajos, 2018; Dhakal and Kattel, 2019). Recent studies observed declines in CES in Alpine 53 pastures and floodplains in Europe in part due to climate change impacts (Probstl-Haider et al., 2016; 54 Schirpke et al., 2019). Another study estimated that the scenic beauty enjoyed by those who visit the 55 vineyards in central Chile will decline by 18-28% by 2050 due to a combination of reduced precipitation, 56 increased temperatures, and natural fire cycles (Martinez-Harms et al., 2017). More research is needed, 57 however, particularly on cultural heritage, spiritually significant places, and in low-income countries. | Heritage | 861 - 861 |
| IPCC | IPCC_AR6_WGII_Full_ Report | Region CES Climate Change Scenario Projected impacts from climate change References Central Chile, South America Aesthetic experience of scenic beauty in vine-growing region. | Heritage | 862 - 862 |
| IPCC | IPCC_AR6_WGII_Full_ Report | Participatory scenario analysis estimated reduction in aesthetic experience from scenic beauty by 18-28% by 2050 for RCP 2.6, with greater impacts under RCP 8.5. | Heritage | 862 - 862 |

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| Organisation | Document | Quotation Content | Codes | Page |
|---|---|---|---|---|
| IPCC | IPCC_AR6_WGII_Full_Report | (2017) Mountainous regions of Austria Cultural and aesthetic experiences in alpine pastures and diverse agricultural landscapes Temperature + 1.5 °C from 2008 to 2040 and 4 precipitation scenarios (High, similar, seasonal shift and Low). | Heritage | 862 - 862 |
| IPCC | IPCC_AR6_WGII_Full_Report | Evaristus (2014) Philippines Nature-based tourism in agri�tourism Not specified Risk of typhoon, drought and strong wind, grass fire, heavy rains. Anticipated to increase vulnerability in terms of human health services and energy use in tourism. | Heritage | 862 - 862 |
| IPCC | IPCC_AR6_WGII_Full_Report | Asia (southwest China) Maize • PPB done primarily with women farmers, led to 1500 landraces safeguarded, 12 farmer-preferred varieties released and 30 landraces released, bred for improved yield (15-20% increases), drought resistance, taste, market potential and other priority traits (Song et al., 2019). | Heritage | 867 - 867 |
| IPCC | IPCC_AR6_WGII_Full_Report | • Studies suggest PPB improved farmer knowledge, income, and access to resilient seeds, and strengthened institutions ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 5 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 5-43 Total pages: 286 such as women-led farmer cooperatives and a Farmer Seed Network of China (Song et al., 2019). | Heritage | 867 - 868 |
| IPCC | IPCC_AR6_WGII_Full_Report | • Diversified landscapes can also enhance cultural ecosystem services, by supporting cultural heritage crops, recreational and aesthetic experiences (medium confidence) (Novikova et al., 2017; Martínez-Paz et al., 2019; Alcon et al., 2020). | Heritage | 869 - 869 |
| IPCC | IPCC_AR6_WGII_Full_Report | 15 16 5.8.4 Adaptation 17 18 Adaptation options in land and aquatic-based culturing food production systems include both governance 19 actions and changes in the factors of production (Section 5.4.4, 5.5.4, Reverter et al., 2020). In contrast, 20 adaptation options in fisheries are primarily concentrated in the socio-economic dimension, especially 21 governance and management (Brander et al., 2018; Holsman et al., 2019), and given the scale of the 22 problem, there are relatively few intentional, well-documented examples of implemented tactical responses 23 (Bell et al., 2020). | Heritage | 899 - 899 |
| IPCC | IPCC_AR6_WGII_Full_Report | 20 21 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 5 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 5-83 Total pages: 286 1 2 Figure 5.13: Global and regional aquaculture production a) world wild capture fisheries and aquaculture inland 3 (freshwater and brackish) and marine production from 1950-2018, b) diversity of aquaculture groups cultured in 2016, 4 and c) regional aquaculture share of total fisheries production, and d) global aquaculture species production in 2018 by 5 region and type (freshwater, brackish, or marine) on a logged scale (FAO, 2018c; FAO, 2020c; FAO, 2020d). | Heritage | 907 - 908 |
| IPCC | IPCC_AR6_WGII_Full_Report | 10 11 Observed impacts on inland systems have generally been site and region specific (high confidence) (Hoegh- 12 Guldberg et al., 2018; Sainz et al., 2019; Lebel et al., 2020). Salinity intrusions into freshwater aquaculture 13 systems have changed oxygen and water quality of inland ponds, resulting in mortalities in areas such as 14 India and Bangladesh (medium confidence) (Dubey et al., 2017; Dabbadie et al., 2018). Rapid changes in 15 temperature, precipitation, droughts, floods and erosion have created significant production losses for aquatic 16 farmers in Cambodia, Laos, Myanmar, Thailand, Viet Nam and Ghana (medium confidence) (Asiedu et al., 17 2017; Pongthanapanic et al., 2019; Lebel et al., 2020). Algal blooming and inland lake browning related to 18 warming was found to negatively affect fish biomass (van Dorst et al., 2018). Observed indirect effects of 19 climate change on aquaculture include extreme weather events that damage coastal aquaculture infrastructure 20 or enable flooding, both leading to animal escapees (e.g. fish, shrimp), damaged livelihoods and interactions 21 with wild species (high agreement, medium evidence) (Beveridge et al., 2018b; Dabbadie et al., 2018; Kais 22 and Islam, 2018; Pongthanapanic et al., 2019; Ju et al., 2020). | Heritage | 909 - 909 |
| IPCC | IPCC_AR6_WGII_Full_Report | 16 17 5.9.2.1 Gender and other social vulnerability and roles in aquaculture 18 19 There are regional differences in women's roles, responsibilities and involvement in adaptation strategies in 20 the aquaculture sector. Women comprise 14% of the 2018 global aquaculture workforce of 20.5 million 21 (FAO, 2020c), representing up to 42% of the salmon workforce in Chile (Chávez et al., 2019), 22 predominantly in processing roles (Gopal et al., 2020). In the majority of lower-middle-income countries 23 seaweed culture is dominated by women in family-owned businesses as in Zanzibar and the Philippines 24 (Brugere et al., 2020; Ramirez et al., 2020), where women are not always paid directly but contribute to 25 family incomes (high confidence) (Msuya and Hurtado, 2017; Brugere et al., 2020; Ramirez et al., 2020). In 26 India women collect stocking juveniles and assist in pond construction, in Bangladesh women do the same 27 tasks as men and in Ghana women undertake post-harvest fishing activities (Lauria et al., 2018). Women 28 employed in aquaculture cooperatives gained adaptive capacity, which reduced gender inequities (medium 29 confidence) (Farquhar et al., 2018; Gonzal et al., 2019), but lack of financial access for women can create 30 gender inequality at larger commercial scales (Gurung et al., 2016; Call and Sellers, 2019).Women in 31 aquaculture experience competing roles between employment, childcare and home duties (high confidence) 32 (Morgan et al., 2015; Lauria et al., 2018; Chávez et al., 2019; see Cross-Chapter Box GENDER in Chapter 33 18), and differ from men in terms of perceptions of environmental risk, climate change, adaptation 34 behaviour, with limited contributions to decision-making (medium confidence) (Barange and Cochrane, 35 2018). Therefore, effective climate aquaculture adaptation options need to address gender inequality e.g. | Heritage | 911 - 911 |

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|---|---|---|---|---|
| IPCC | IPCC_AR6_WGII_Full_Report | 7 8 9 5.9.3.2 Marine aquaculture 10 11 5.9.3.2.1 Finfish culture 12 Global projections of ocean warming, primary productivity and ocean acidification predict suitable habitat 13 expansions and short-term growth benefits for finfish aquaculture for some regions (medium confidence) (see 14 Figure 5.15) until thermal tolerances or productivity constraints are exceeded by 2090 (Beveridge et al., 15 2018b; Dabbadie et al., 2018; Froehlich et al., 2018a; Catalán et al., 2019; Thiault et al., 2019; Falconer et 16 al., 2020a). Sensitivities for marine finfish may be high even under +1.5-2.0°C (medium confidence) 17 (Gattuso et al., 2018), resulting in finfish farms moving northward to maintain productivity (e.g., Arctic 18 (Troell et al., 2017). Downscaled projections of regionally specific tolerances (Klinger et al., 2017) may be 19 particularly useful for management and planning; a 0.5°C rise is predicted for Chilean salmon aquaculture 20 (Soto et al., 2019) and potential projected negative impacts on productivity in Norway by 2029 (limited 21 evidence) (Falconer et al., 2020a). Marine heatwaves are predicted to increase in occurrence, intensity, and 22 persistence under RCP4.5 or RCP8.5 by 2100 (Oliver et al., 2019; Bricknell et al., 2021) with risk partly 23 mitigated by husbandry (medium confidence) (McCoy et al., 2017). Generally, negative impacts are 24 predicted for marine species with residual risk increasing with level of exposure (Sara et al., 2018; Smale et 25 al., 2019), where warming will affect oxygen solubility and reduce salmon culture capacity (limited 26 evidence) (Aksnes et al., 2019, Chapter 3) and combine with increasing incidence of harmful algal blooms 27 (high confidence) resulting in negative impacts for food security and nutrition and health (Oppenheimer et 28 al., 2019; Colombo et al., 2020; Glibert, 2020; Raven et al., 2020). Climate change is predicted to affect the 29 incidence, magnitude and virulence of finfish disease, e.g., Vibriosis (Barber et al., 2016; Mohamad et al., ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 5 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 5-88 Total pages: 286 1 2019a; Mohamad et al., 2019b), but specific host-pathogen-climate relationships are not yet established (high 2 confidence) (Slenning, 2010; Marcogliese, 2016; Montanchez et al., 2019; Bandin and Souto, 2020; 3 Behringer et al., 2020; Filipe et al., 2020; Montanchez and Kaberdin, 2020). Projected climate change will 4 also increase competition for feed ingredients between aquatic and terrestrial animal production systems (see 5 Section 5.13.2.). | Heritage | 912 - 913 |
| IPCC | IPCC_AR6_WGII_Full_Report | 6 7 5.9.3.2.2 Shellfish culture 8 Globally, there is overall high confidence that suitable shellfish aquaculture habitat will decline by 2100 9 under projected warming, ocean acidification and primary productivity changes, with significant negative 10 impacts for some regions and species before 2100 (Table 5.9, Froehlich et al., 2018a; Ghezzo et al., 2018). | Heritage | 913 - 913 |
| IPCC | IPCC_AR6_WGII_Full_Report | 25 26 5.9.3.2.3 Aquatic plant culture 27 There is medium confidence that cultivated seaweeds are predicted to suffer habitat loss resulting in 28 population declines and northward shifts (Table 5.11). | Heritage | 913 - 913 |
| IPCC | IPCC_AR6_WGII_Full_Report | 29 30 31 Table 5.11: Projected impacts of climate on specific inland, brackish, and marine culture systems and species. | Heritage | 913 - 913 |
| IPCC | IPCC_AR6_WGII_Full_Report | (2020) Temperature increase, ocean acidification Ecopath with RCP 8.5 by 2100 (2.8°C warming and pH 7.89) U.S. Marine Shellfish Reduction primary productivity and subsequent bivalve carrying capacity Chapman et al. (2020) Temperature increase, stratification change RCP8.5 by 2088-2099 Spain Marine Mussels Decline in mussel optimal culture conditions of 60% in upper and 30% in deeper waters by 2099 Des et al. | Heritage | 914 - 914 |
| IPCC | IPCC_AR6_WGII_Full_Report | 1 2 3 5.9.3.2.4 Societal impacts within the production system 4 Marine aquaculture provides distinct ecosystem services through provisioning (augmenting wild fishery 5 catches), regulating (coastal protection, carbon sequestration, nutrient removal, improved water clarity), 6 habitat and supporting (artificial habitat) and cultural (livelihoods and tourism) services (Gentry et al., 2020), 7 which vary with species, location, and husbandry (Alleway et al., 2019). Projected thermal increases of 8 1.5°C will reduce ecosystem services, further reduced under 2°C warming, with associated increases in 9 acidification, hypoxia, dead zones, flooding, and water restrictions (medium confidence) (Hoegh-Guldberg et 10 al., 2018). Sudden production loses from extreme climate events can exacerbate food security challenges 11 across production sectors, including aquaculture, increasing global hunger (high confidence) (Cottrell et al., 12 2019; Food Security Information Network, 2020). While aquaculture provides positive influences such as 13 food security and livelihoods, there are negative concerns over environmental impacts (including high 14 nutrient loads from sites) and socio-economic conflicts (Alleway et al., 2019; Soto et al., 2019) and adoption 15 of ecosystem approaches are dependent on particular user groups and regions (Gentry et al., 2017; Brugère et 16 al., 2019; Gentry et al., 2020). In coastal Bangladesh projected saline inundation to wetland ecosystem 17 services will result in ecosystem services losses of raw materials and food provisioning, ranging from USD 18 0-20.0 million under RCP2.6 to RCP8.5 scenarios (Mehvar et al., 2019). Mangrove deforestation for shrimp 19 farming in Asia negatively impacts ecosystem services and reduces climate resilience (medium confidence) 20 (Mehvar et al., 2019; Nguyen and Parnell, 2019; Reid et al., 2019; Custódio et al., 2020), while mangrove 21 reforestation efforts may have some effectiveness in recreating important nursery grounds for aquatic species 22 (low confidence) (Gentry et al., 2017; Chiayarak et al., 2019; Hai et al., 2020). Families are highly vulnerable 23 to climate change where nutritional needs are being met by self-production, e.g., Mozambique, Namibia 24 (Villasante et al., 2015), Zambia (Kaminski et al., 2018) and Bangladesh (high confidence) (Pant et al., 25 2014). Climate change will therefore affect multiple ecosystem services where ultimately decisions on 26 balance or trade-offs will vary with regional perceptions of service value (high confidence). | Heritage | 915 - 915 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 5 6 7 5.9.4.2 Species selections and selective breeding 8 Adaptation options at the operational level include species selections, e.g., cultivation of brackish species 9 (shrimp, crabs) during dry seasons, and rice-finfish in wetter seasons in Thailand (Chiayarak et al., 2019), 10 use of salt-tolerant plants in Viet Nam (Nhung et al., 2019; Paik et al., 2020), converting inundated rice 11 paddies into aquaculture, rotating shrimp, and rice culture (high confidence) (Chiayarak et al., 2019). Species 12 diversification through co-culture, integrated aquaculture-agriculture (e.g. rice-fish) or integrated multi- 13 trophic culture (e.g. shrimp-tilapia-seaweed or finfish-bivalve-seaweed) may maintain farm long-term 14 performance and viability by: creating new aquaculture opportunities; promoting societal and environmental 15 stability; reducing GHG emissions through reduced feed usage and waste, and; carbon sequestration 16 (medium confidence) ( see Section 5.10, Li et al., 2019; Galappaththi et al., 2020b; Prakoso et al., 2020; Tran 17 et al., 2020) (Ahmed et al., 2017; Bunting et al., 2017; Gasco et al., 2018; Soto et al., 2018; Ahmed et al., 18 2019; Dubois et al., 2019; FAO, 2019c; Freed et al., 2020). In practice, most aquaculture operations 19 concentrate on single-species systems (Metian et al., 2020) and barriers such as land availability, freshwater 20 resources and lack of credit access may limit the uptake and success of integrated adaptation approaches to 21 climate change (Ahmed et al., 2019; Tran et al., 2020; Kais and Islam, 2021). | Heritage | 917 - 917 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 44 45 5.9.4.3 Farm site selection, infrastructure, and husbandry 46 47 Land-based aquaculture systems including hatcheries may reduce exposure to climatic extremes (due to 48 better control of the culture environment), limit water usage, reduce juvenile reliance and buffer climate 49 effects using optimal diets (high confidence) (Barton et al., 2015; Reid et al., 2019; Cominassi et al., 2020). | Heritage | 917 - 917 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 55 56 Geographical selection of marine farm sites may prevent climate productivity declines (medium confidence) 57 (Froehlich et al., 2018a; Sainz et al., 2019; Oyinlola et al., 2020), particularly for temperature–related ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 5 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 5-93 Total pages: 286 1 mortality hotspots (Garrabou et al., 2019), harmful algal bloom occurrences (Dabbadie et al., 2018) or 2 extreme events (Liu et al., 2020; Wu et al., 2020). However, while downscaled climate forecasts facilitate 3 localized adaptation planning (Falconer et al., 2020a), such projections are rare (Whitney et al., 2020). GIS 4 can be used for climate adaptive planning along with routine site assessments (Falconer et al., 2020b; 5 Galappaththi et al., 2020b; Jayanthi et al., 2020). Building coastal protection, stronger cages and mooring 6 systems, deeper ponds and using sheltered bays can reduce escapees and mortalities related to flooding, 7 increased storms and extreme events (medium confidence) (Dabbadie et al., 2018; Bricknell et al., 2021; Kais 8 and Islam, 2021). Inshore aquaculture in low-lying areas prone to sea-level salinity intrusion (e.g. Mekong 9 delta and Viet Nam) have already implemented adaptation measures, such as conversion of land to mixed 10 plant-animal systems (Nguyen et al., 2019a), converting freshwater ponds to brackish or saline aquaculture 11 (Galappaththi et al., 2020b), building of dams and dykes (Renaud et al., 2015) and intensification of shrimp 12 or fish pond culture to reduce water and land usage (Nguyen et al., 2019b; Johnson et al., 2020). Other 13 adaptation options for limited water supply are government equitable water allocations and water storage 14 (high confidence) (Bunting et al., 2017; Galappaththi et al., 2020b). | Heritage | 917 - 918 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 22 Insurance covers natural disasters and disease, helping to reduce and cope with climate-induced risk, 23 enabling faster livelihood recoveries and preventing poverty (high agreement, limited evidence) (Xinhua et 24 al., 2017; Kalikoski et al., 2018; Soto et al., 2018). For example, small-scale shrimp farmers were willing to 25 pay higher premiums to manage risk, after participation in government pilot insurance schemes, ensuring 26 greater pay-outs if a mortality event occurred (Nyguyen and Pongthanapanic, 2016; Pongthanapanic et al., 27 2019). Technological innovations are more widely implemented in larger operations, with internet access 28 promoting adoption at the farm site (Joffre et al., 2017; Salazar et al., 2018). Improved farm management is a 29 key opportunity (high confidence) to reduce climate risks on aquaculture, where Best Management Practices 30 can increase resiliency (Soto et al., 2018), lower additional risk from non-climatic stressors (Gattuso et al., 31 2018; Smith and Bernard, 2020), and decision-tree frameworks can provide adaptation choices when events 32 occur (Nguyen et al., 2016). | Heritage | 918 - 918 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 33 34 5.9.4.4 Early warning and monitoring systems 35 36 Globally monitoring is increasing to fill scientific uncertainties (Goldsmith et al., 2019), but is not often at 37 spatial scales which facilitate farm or regional adaptation management (Whitney et al., 2020) or data 38 complexities prevent direct uptake by operators, resource managers and policymakers (medium confidence) 39 (Soto et al., 2018; Gallo et al., 2019). Specialized industry portals (Pacific shellfish) and government- 40 established monitoring programs (Chilean salmon) and other observational networks (e.g., GOA-ON) can 41 provide real-time monitoring, early-warning event alerts and facilitate aquaculture decision-making (medium 42 confidence) (Cross et al., 2019; Farcy et al., 2019; Soto et al., 2019; Bresnahan et al., 2020; Peck et al., 2020) 43 (Tilbrook et al., 2019). Seasonal forecasting, downscaled models and early-warning systems provide 44 valuable regional or farm site risk information (Hobday et al., 2018; Galappaththi et al., 2020b; Whitney et 45 al., 2020), but monitoring will need to be useful for farmers, involve farmers, accurate, timely, cost-effective, 46 reviewed and maintained in order to ensure uptake (high confidence) (Soto et al., 2018). Early warning 47 systems for harmful algal blooms enable rapid decision-making and risk mitigation (medium confidence), 48 e.g., ocean colour monitoring in South Africa (Smith and Bernard, 2020), where early harvesting and 49 additional husbandry were used to minimize production and economic losses (Pitcher et al., 2019). New 50 tools, strategies and observations are needed to predict harmful algal bloom occurrences and range shifts 51 with changing climate (high confidence) (Schaefer et al., 2019; Tester et al., 2020), as there is uncertainty on 52 drivers of incidence and toxicity (Wells et al., 2020). | Heritage | 918 - 918 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | (2019), Amadou et al. (2020) Increased productivity per unit of land Introduction of multiple species leading to higher land equivalency ratios van Noordwijk et al. (2018), Reppin et al. (2019) Improved biophysical site properties Via limiting soil erosion, facilitating water infiltration, increasing nutrient use efficiency, improving soil physical properties, improving crop nutritional quality, modifying the site micro-climate, and helping to buffer against extreme events Nguyen et al. (2013); Carsan et al. (2014), Rosenstock et al. | Heritage | 924 - 924 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 6 7 8 [START BOX 5.8 HERE] 9 10 Box 5.8: Climate Adaptation and Maladaptation in Cocoa and Coffee Production 11 12 Coffee and cocoa are important crops in low latitude regions where agriculture is projected to be heavily 13 impacted by climate change. Both crops are at risk from climate change impacts by 2050 (Baca et al., 2014; 14 Ovalle-Rivera et al., 2015; Chemura et al., 2016; Schroth et al., 2016; Bacon et al., 2017; Schreyer et al., 15 2018; de Sousa et al., 2019; Lahive et al., 2019; Pham et al., 2019; Cilas and Bastide, 2020). Chocolate and 16 coffee are notable among foods in that their carbon footprint ranges from negative to high, as these industries 17 include both low-input agroforestry systems that have many co-benefits, and high-input monoculture systems 18 where crops are grown without shade, in some cases on sites that have been deforested (Poore and Nemecek, 19 2019). While the coffee industry in many countries has already transitioned from agroforestry to a full-sun 20 production (Jha et al., 2014), the cocoa industry is at a turning point with many growers deciding whether to 21 move to the potentially more productive 'full-sun system', despite a general view that the agroforestry 22 system is more resilient to climate change impacts (Rajab et al., 2016; Schroth et al., 2016; Farrell et al., 23 2018; Niether et al., 2020). | Heritage | 926 - 926 |
| IPCC | IPCC_AR6_WGII_Full_ Report | (2019) Loss of habitat, degradation of savannas, native grasslands (grassy biomes) or mangroves wrongly characterized as degraded land suitable for afforestation Right to a healthy environment, right to food Robust evidence, high agreement Veldman et al: (2015), Cormier-Salem and Panfili (2016), Brancalion and Chazdon (2017), Bond et al. (2019), Seddon et al. (2020) Direct negative health impacts; loss of traditional medicine Right to health Limited evidence, medium agreement Dotchamou et al. (2016), Johansson and Isgren (2017) A/R projects affect burial sites as for many communities, the forest is also the resting place for deceased ancestors Right to cultural identity and to main and control their traditional knowledge Limited evidence, high agreement Lyons et al. (2014), Gabriel and Mangahas (2017), Mousseau and Teare (2019) Loss of traditional or Indigenous ecological knowledge and forest management practices Right to cultural identity and traditional knowledge Limited evidence, medium agreement Bayrak and Marafa (2016) Increased labor burden. Benefit sharing by direct cash transfer or in-kind modalities tends to not compensate lost income opportunities. Some projects bring employment opportunities, but these are short term and limited and rarely viable if the opportunity cost of land and labour is considered. Poor farmers may drop out in order to regain access to their land for uses that provide cash returns in the shorter term. | Heritage | 957 - 957 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 9 10 The framing of 'key economic sectors and services' in AR5 focused primarily on three infrastructural areas 11 (energy, water services, transport) and on primary and secondary economic activities (including recreation 12 and tourism, insurance and financial services). Cities, settlements and key infrastructure are also referred to 13 in the IPCC special reports released since AR5. The Special Report on Global Warming of 1.5°C examines 14 impacts of global warming on urban systems and infrastructure in the context of advancing sustainable 15 development and eradicating poverty. It highlights the risks facing residents of unplanned and informal 16 urban settlements, many of which are exposed to a range of climate-related hazards (Sections 3.4.8 and 17 4.4.1.3). The Special Report on Global Warming of 1.5°C also identifies green infrastructure, sustainable 18 land use and planning, and sustainable water management as key adaptation options that can reduce risks in 19 urban areas (SPM C2.4; C. 2.5), and highlights "urban and infrastructure" as one of four system transitions 20 required to limit warming to 1.5°C to create an enabling environment for adaptation (Section 4.3.3). | Heritage | 1120 - 1120 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 4 5 6.1.4 Global Urban Trends 6 7 Since AR5, many cities and other settlements, particularly unplanned and/or informal in Asia and Africa, 8 have continued to grow at rapid rates (van den Berg , Otto and Fikresilassie 2021). Elsewhere, in Latin 9 America in particular, while growth is less rapid, inequality persists. As a result, cities and settlements are 10 crucial both as sites of potential action on climate change, and sites of increased exposure to risk (medium 11 evidence, high agreement). | Heritage | 1124 - 1124 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 11 12 As a blueprint for advancing human dignity, the Sustainable Development Goals emphasize the need to 13 consider how to achieve a better and more sustainable future while 'leaving no one behind.' In doing so, they 14 highlight an agenda focused on wellbeing, equality and justice. The objective for SDG11 is defined as: 15 "Make cities and human settlements inclusive, safe, resilient and sustainable" with ten associated targets 16 including ensuring access for all to adequate, safe and affordable housing and basic services; participatory 17 planning; safeguarding heritage features; reducing disasters particularly water related disasters and economic 18 impacts on the poor; and promoting resource efficiency, mitigation and adaptation to climate change, 19 resilience to disasters, and develop and implement plans, in line with the Sendai Framework for Disaster 20 Risk Reduction. Similarly SDG9 aims to build resilient infrastructure, promote inclusive and sustainable 21 industrialization and foster innovation, with associated targets. The IPCC 1.5 special report emphasized that 22 there are often cobenefits in pursuit of SDGs and adaptation strategies where "well-designed mitigation and 23 adaptation responses can support poverty alleviation, food security, healthy ecosystems, equality and other 24 dimensions of sustainable development" (Masson-Delmotte et al., 2018 FAQ 5.1). However there may also 25 be negative trade-offs for example between pursuit of growth and reducing climate change risk (International 26 Council for Science, 2017; Masson-Delmotte et al., 2018 Executive Summary; Roy et al., 2018). | Heritage | 1129 - 1129 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 13 Shading indicates projected number of days in a year in which conditions of air temperature and humidity surpass a 14 common threshold beyond which climate conditions turned deadly and pose a risk of death (Mora et al., 2017b). Named 15 cities are top fifteen urban areas by population size during 2020, 2050, and 2100 respectively as projected by Hoornweg 16 and Pope (2017) 17 18 19 Locally, the urban heat island also elevates temperatures within cities relative to their surroundings. It is 20 caused by physical changes to the surface energy balance of the pre-urban site from urbanization, resulting 21 from the thermal characteristics and spatial arrangement of the built environment, and anthropogenic heat 22 release ((Oke et al., 2017; Chow et al., 2014; Susca and Pomponi, 2020); WGI FAQ10.1). A considerable 23 body of evidence exists on how the multi-scale impacts and consequent risks arise when local elevated 24 temperatures within settlements are enhanced by climate change, with specific elements of this affecting 25 megacities (Darmanto et al., 2019). The urban heat island itself is amplified during heat waves (Founda and 26 Santamouris, 2017), but the extent to which varies regionally and by time of day (Ward et al., 2016a; Zhao et 27 al., 2018b; Eunice Lo et al., 2020). When combined with warming induced by urban growth, extreme heat ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 6 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 6-23 Total pages: 183 1 risks are expected to affect half of the future urban population, with a particular impact in the tropical Global 2 South and in coastal cities and settlements ((Huang et al., 2019); CCP2.2.2; Table CCP2.A.1). | Heritage | 1133 - 1134 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 24 25 Social surveys from temperate and tropical cities highlight the risk of reduced quality of life during heat 26 events, including increased incidence of personal discomfort in indoor and outdoor settings, elevated anxiety, 27 depression, and other indicators of adverse psychological health, and reductions in physical activity, social 28 interactions, work attendance, tourism, and recreation (high confidence) (Chow et al., 2016; Elnabawi, 29 Hamza and Dudek, 2016; Obradovich and Fowler, 2017; Wang et al., 2017; Wong et al., 2017; Lam, 30 Loughnan and Tapper, 2018; Alves, Duarte and Gonçalves, 2016). Extreme heat may also have a cultural 31 impact, for example affecting major sporting events, with negative impacts on the athletic performance 32 (Brocherie, Girard and Millet, 2015; Casa et al., 2015) and the experience and health of spectators 33 (Hosokawa, Grundstein and Casa, 2018; Kosaka et al., 2018; Matzarakis et al., 2018; Vanos et al., 2019). | Heritage | 1135 - 1135 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 35 36 Even where formal planning is the norm, this has often remained oriented toward enabling value adding 37 construction or the protection of existing high value physical assets, e.g., infrastructure and built cultural 38 heritage; private residential) rather than enabling disaster risk reduction for all (Long and Rice, 2019). This 39 tendency has been widely documented, including from cases in Australia, Thailand and Indonesia (King et 40 al., 2016), Canada (Stevens and Senbel, 2017), Amman, Moscow, and Delhi (Jabareen, 2015), and South 41 Africa (Arfvidsson et al., 2017). Such inconsistencies between the delivery of land-use planning and the aims 42 of the Sustainable Development Goals combine with other social structures, economic pathways, and 43 governance systems to shape city risk profiles (Dodman et al., 2017). | Heritage | 1141 - 1141 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 29 Infrastructure can be broadly understood to include social infrastructure (housing, health, education, 30 livelihoods and social safety nets, security, cultural heritage/institutions, disaster risk management and urban 31 planning), ecological infrastructure (clean air, flood protection, urban agriculture, temperature, green 32 corridors, watercourses and riverways) and physical infrastructure (energy, transport, communications 33 (including digital), built form, water and sanitation and solid waste management) (Thacker et al., 2019). This 34 section focuses especially on physical infrastructure where the literature provides discrete risk and impact 35 assessments. Physical infrastructure systems are often immobile, indivisible, involve high fixed costs, and 36 have longer lifecycles. Social and ecological infrastructure elements are rarely assessed alone and instead 37 tend to be included in wider assessments of event impacts. | Heritage | 1143 - 1143 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 21 22 6.2.4.6 Natural and Ecological Infrastructure 23 24 Urban ecological infrastructure includes green (i.e., vegetated), blue (i.e., water-based), and grey (i.e., non- 25 living) components of urban ecosystems (Li et al., 2017). While land cover change from urbanization 26 directly reduces the extent of natural and ecological infrastructure (e.g. Lin, Meyers and Barnett, 2015), 27 notable risks arise from climate drivers. Recent research particularly highlights future climate impacts on 28 coastal natural infrastructure – including beaches, wetlands, and mangroves – which cause significant 29 economic losses from property damage, decreasing tourism income, as well as loss of natural capital and 30 ecosystem services. Research on climate risks to urban trees and forests is comparatively limited. Instead, 31 urban vegetation and green infrastructure are most often cast as adaptation strategies to reduce urban heat, 32 mitigate drought, and provide other ecosystem benefits (see 6.3.2). | Heritage | 1149 - 1149 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 5 6 Climate risks to urban natural and ecosystem infrastructure entail significant economic costs. For example, in 7 2012, Hurricane Sandy led to total losses of up to US$6.5 million to the New York City region's low-lying 8 salt marshes and beaches (Meixler, 2017). Research from coastal settlements across Catalonia, Spain, shows 9 significant levels of tourism loss (which contribute to 11.1% of the region's GDP), infrastructure damage, 10 and natural capital loss attributed to inundation and erosion of beaches, which are projected to retreat by -0.7 11 meters per year given current sea level rise projections of 0.53 to 1.75 meters by 2100 (Jiménez et al., 2017). | Heritage | 1150 - 1150 |

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| IPCC | IPCC_AR6_WGII_Full_Report | 41 42 Human behaviour can exacerbate climate impacts – for example in the emergence of 'last chance 43 tourism'(Lemieux et al., 2018) focused on built cultural heritage at risk from climate change associated 44 events including from decay or even total loss generated by increased flooding and sea-level rise (Camuffo, 45 Bertolin and Schenal, 2017) and water infiltration from post-flood standing water (Camuffo, 2019). Last 46 chance tourism can lead to increased touristic interest over a short time horizon and to precarious economic 47 conditions, which can lead to further accelerated degradation cultural heritage sites already at-risk from 48 climate change. | Heritage | 1153 - 1153 |
| IPCC | IPCC_AR6_WGII_Full_Report | 7 8 9 6.3 Adaptation Pathways 10 11 6.3.1 Introduction 12 13 Adaptation pathways are composed of sequences of adaptation actions connected through collaborative 14 learning with the possibility of enabling transformations in urban and infrastructure systems (Werners et al., 15 2021). Individual adaptation actions co-evolve with risks (see Section 6.2) and development processes 16 (Section 6.4) to compose more or less planned adaptation pathways, that can include a range of unanticipated 17 outcomes. This section engages with this complexity by approaching adaptation through the notion of 18 infrastructure. The adaptation options for individual infrastructure systems are reviewed, and in Section 6.4 19 brought together through assessment of cross-cutting enabling conditions. Interpreted broadly, infrastructure 20 includes the social systems, ecological systems and grey/physical systems that underpin safe, satisfying and 21 productive life in the city and beyond (Grimm et al., 2016). Social infrastructure includes housing, health, 22 education, livelihoods and social safety nets, cultural heritage/institutions, disaster risk management and 23 security and urban planning. Ecological infrastructure includes nature-based services: temperature 24 regulation, flood protection and urban agriculture. Grey, or physical infrastructure includes energy, transport, 25 water and sanitation, communications (digital), built form and solid waste management. Framing 26 infrastructure in this way enables an assessment of adaptation that is not constrained to the administrative 27 boundaries of urban settlements, but also includes the flows of material, people and money between urban, 28 peri-urban and more rural places and can include adaptation actions deployed by government, individuals 29 and the private sector. Recognising the complexity of adaptation and the research literature that reaches 30 beyond individual infrastructural domains, the section also reviews urban adaptation through the cross- 31 cutting lenses of equity and mitigation. Section 6.4 assesses the enabling environment (political will, 32 governance, knowledge, finance and social context) that shapes specific adaptation contexts and futures. | Heritage | 1158 - 1158 |
| IPCC | IPCC_AR6_WGII_Full_Report | 27 28 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 6 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 6-49 Total pages: 183 1 2 Figure 6.4: The Urban Adaptation Gap. Notes: This is a qualitative assessment presenting individual, non-comparative 3 data for world regions from 25 AR6 CLAs and LAs, the majority from regional chapters. Respondents were asked to 4 make expert summary statements based on the data included within their chapters and across the AR6 report augmented 5 by their expert knowledge. Multiple iterations allowed opportunity for individual and group judgement. Urban 6 populations and risks are very diverse within regions making the presented results indicative only. Variability in data 7 coverage leads to the overall analysis having medium agreement – medium evidence. Major trends identified in 6.3.1 at 8 least meet this level of confidence. Analysis is presented for current observed climate change associated hazards and for 9 three adaptation scenarios: (1) current adaptation (based on current levels of risk management and climate adaptation), 10 (2) planned adaptation (assessing the level of adaptation that could be realised if all national, city and neighbourhood 11 plans and policies were fully enacted), (3) transformative adaptation (if all possible adaptation measures were to be 12 enacted). Assessments were made for the lowest and highest quintile by income. Residual risk levels achieved for each 13 income class under each adaptation scenario are indicated by five adaptation levels: no risk, occasional discomfort, 14 occasional impacts on wellbeing, frequent impacts on wellbeing, extreme events and/or chronic risk. The urban 15 adaptation gap is revealed when levels of achieved adaptation fall short of delivering 'no risk'. The graphic uses IPCC 16 Regions, and has split Asia into two regions: North and East Asia, and Central and South Asia. Technical support is 17 acknowledged from Greg Dodds and Sophie Wang 18 19 20 6.3.3 Adaptation Through Social Infrastructure 21 22 Social infrastructure refers to social, cultural and financial activities and institutions as well as associated 23 property, buildings and artefacts that can be deployed to reduce risk and recover from loss. This section 24 examines land use planning, livelihoods and social protection, emergency and disaster risk management, 25 health systems, education and communication, and cultural heritage. | Heritage | 1159 - 1160 |
| IPCC | IPCC_AR6_WGII_Full_Report | Multiple programs for differing household needs in Philippines (Bowen et al., 2020) Weather-index insurance in Chinese coastal cities (Rao and Li, 2019); Early warning forecast system and public meteorological service information in Beijing (Song, Zheng and Lin, 2021) Promotive and anticipatory measures; transformational adaptation 7 8 9 Adaptive Social Protection (ASP) may be very good at reducing extreme poverty by helping to meet 10 individual or household needs but not collective needs to mitigate long-term climate shocks. For example, 11 few programmes consider risk assessment and climate-proof infrastructures as anticipatory measures to 12 foster early action and preparedness (Aleksandrova, 2019; Costella et al., 2017). They therefore need to 13 enable the adoption of forward-looking strategies for long-lasting adaptation (Tenzing, 2020). Some 14 examples from China show social protection can improve adaptive capacity of urban communities with 15 social medical insurance, housing subsidies, weather-index insurance, post disaster construction, relocation 16 planning, livelihood shift strategies, and so on (Pan et al., 2015; Zheng et al., 2018b; Rao and Li, 2019; 17 Song, Zheng and Lin, 2021). However, social protection may lead to maladaptation in urban policy when 18 social security, or similar tools (for example insurance) compensate for exposure deincentivise risk reduction 19 (Grove, 2021). In many developing countries, high concentration of poor and vulnerable groups living in 20 disaster-prone zones of urban centres, new urban dwellers and informal residents are often excluded from 21 community-based networks and social services (Aleksandrova, 2019). Risk transfer tools (like insurance) 22 and risk retention measures (like social safety nets) can avoid and minimise the burden of loss and damage 23 and limit secondary and indirect effects (Aleksandrova, 2019; Roberts and Pelling, 2018). | Heritage | 1163 - 1163 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 29 30 6.3.3.6 Cultural heritage/institutions 31 32 The integration of culture into urban policy and planning is increasingly recognised as critical to developing 33 sustainable and resilient cities and features in international agreements such as the SDGs (limited evidence; 34 high agreement) (Sitas, 2020). However, urban cultural policies are still limited, for example, Cape Town is 35 the only African city to have developed a city level cultural policy (Sitas, 2020). Cultural heritage refers to 36 both tangible (e.g. historic buildings and sites) and intangible (e.g. oral traditions and social practices) 37 resources inherited from the past (Fatorić and Egberts, 2020; Jackson, Dugmore and Riede, 2018). Learning 38 about past societal and environment changes through heritage offers opportunity for reflection, transfer of 39 knowledge and skills. This takes place in multiple contexts such as museums and cultural landscapes, and in 40 everyday life (Fatorić and Egberts, 2020; Jackson, Dugmore and Riede, 2018). Cultural heritage is primarily 41 associated with identity and is closely intertwined with the complexities of history, politics, economics and 42 memory. Climate change adds another layer of complexity to cultural heritage and resource management 43 (Fatorić and Seekamp, 2017). Changing climatic conditions are already negatively impacting World Heritage 44 Sites such as the Cordilleras' Rice Terraces of the Philippines and earthen architecture sites - for example the 45 Djenné mosque in Mali are particularly vulnerable to changes in temperature and water interactions 46 (UNESCO, 2021). Climate change impacts intangible cultural heritage across diverse settings such as in the 47 Caribbean and Pacific SIDS where traditional ways of life and related aspects such as oral traditions and 48 performing arts are under threat from extreme weather events (UNESCO, 2021). | Heritage | 1167 - 1167 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 49 50 The climate change adaptation options for built cultural heritage fall into seven categories (Rockman et al., 51 2016; Fatorić and Seekamp, 2017). Financial constraints are the primary barriers that underpin the first four 52 adaptation options: no action at all, merely monitoring and/or documenting, or annual maintenance (Xiao et 53 al., 2019; Sesana et al., 2019; Fatoric and Seekamp, 2017; Fatorić and Seekamp, 2017; Fatorić and Seekamp, 54 2018). Core and shell preservation, the fifth and sixth categories, are cost effective when they improve the 55 condition of built cultural heritage (BCH) (Bertolin and Loli, 2018; Loli and Bertolin, 2018a; Loli and 56 Bertolin, 2018b), while elevation and/or relocation, the final adaptation options, are extremely costly and 57 might jeopardize the historic value (Xiao et al., 2019). To date, however, evidence indicates that adaptation ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 6 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 6-57 Total pages: 183 1 actions prioritize archaeological sites (Carmichael et al., 2017; Fatorić and Seekamp, 2018; Pollard et al., 2 2014; Dawson, 2013). The efficacy of adaptation of historic buildings can be increased through increased 3 and stable funding, incentives, stakeholder engagement, and legal and political frameworks (Dutra et al., 4 2017; Fatorić and Seekamp, 2018; Fatorić and Seekamp, 2017; Fatoric and Seekamp, 2017; Leijonhufvud, 5 2016; Phillips, 2015; Sesana et al., 2019; Sesana et al., 2018; Sitas, 2020). | Heritage | 1167 - 1168 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 6 7 Other barriers to implementation include harnessing expert and local knowledge (of individuals and 8 organizations) to identify both quantitative and qualitative methods and indicators that connect cultural 9 significance and local values vis-à-vis climatic change over time and that move beyond the prevalent high 10 risk- or high vulnerability-centred approaches (Carmichael et al., 2017; Fatorić and Seekamp, 2018; Haugen 11 et al., 2018; Leijonhufvud, 2016; Pollard et al., 2014; Puente-Rodríguez et al., 2016; Richards et al., 2018; 12 Dawson, 2013; Filipe, Renedo and Marston, 2017; Kotova et al., 2019). This is particularly important given 13 that the significance of cultural heritage is often intangible, and its value cannot be determined solely 14 through quantitative indicators. Accessing local resources (craftsmanship and materials compatible with the 15 originals) can also improve built cultural heritage's adaptation capacity (Phillips, 2015). | Heritage | 1168 - 1168 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 16 17 Effective decision making and practice for adapting built and intangible cultural heritage requires open 18 dialogue and exchange of cultural, historical and technical information between diverse stakeholders and 19 decision-makers (Fatorić and Seekamp, 2017; Benson, Lorenzoni and Cook, 2016). As noted in Section 20 6.2.6, human behaviour can be a driving force for adaptation impacts on built cultural heritage at risk. | Heritage | 1168 - 1168 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 21 Despite challenges associated with intangibility, socio-cultural heritage such as Indigenous knowledge (e.g. | Heritage | 1168 - 1168 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 22 food security and water management practices) presents important opportunities for climate adaptation and 23 resilience building. More research is needed across diverse contexts to understand feasible climate adaptation 24 measures and barriers and opportunities for building the resilience of both built and intangible cultural 25 heritage, as well as to increase awareness of cultural heritage benefits among climate change policymakers 26 (Fatorić and Egberts, 2020). | Heritage | 1168 - 1168 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 26 Public actors can benefit from the private sector's innovation and implementation capacity, and businesses 27 can de-risk investments. Still, partnerships can also strengthen the ideologies of growth and managerialism 28 within the operations of the local government (Taylor et al., 2012). Reconciling divergent norms and routines 29 within public and private organizations remains one of the challenges to establishing successful public- 30 private partnerships for adaptation (Lund, 2018). Administrative and political culture influences the nature of 31 interactions between public and private sector actors in urban adaptation agendas (Bauer and Steurer, 2014) 32 with negative consequences such as the imposition of vertical chains of commands on horizontal 33 collaborations, and the need to formalize contractual relations (Klein and Juhola, 2018). | Heritage | 1193 - 1193 |

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| Organisation | Document | Quotation Content | Codes | Page |
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| IPCC | IPCC_AR6_WGII_Full_ Report | 56 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 6 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 6-83 Total pages: 183 1 Unnikrishnan et al (2018) have documented how the colonial and postcolonial history of water management 2 in Bengaluru shapes the water infrastructure and provision systems today. Water access inequalities can be 3 traced to the patterns of spatial development developed by colonial policies. Records from the 6th century 4 onwards show how city rulers invested in an interconnected, community-managed network of tanks and 5 open wells, regularly recharged through harvested rainwater. The water system was changed at the end of the 6 18th century, as first the colonial state, then the post-independence government of Karnataka took 7 responsibility for water management. Ideas of modernist planning influenced the development of new water 8 infrastructure and piped networks, including the first piped infrastructure, bringing water from sources 30km 9 away, including the Hesaraghatta and then the TG Halli reservoirs. The old network of tanks gradually 10 deteriorated as tanks became disused, polluted, or built over. More prolonged and costly water transfers took 11 place in the post-colonial period, delivering water from the Cauvery river in a massive engineering project 12 with a high energetic cost and enmeshed in inter-state conflicts over water use (Castán Broto and Sudhira, 13 2019). Scarcity is still a problem in Bengaluru. The citizen response has been an activist movement to 14 reclaim the city's tanks, accompanied by a plea to reconsider current water uses within the city, including 15 actions to protect and rejuvenate water wells (Nagendra, 2016). Unnikrishnan et al (2018) document 16 different actions led by citizen-led collectives, including projects for lake rejuvenation, filtering technologies 17 to treat sewage, recovering the value of lakes through a share of photos and art projects, and involvement of 18 local knowledge in-tank restoration. Those efforts suggest an untapped potential to deliver adaptive green 19 spaces through the recovery of Bengaluru's tanks. | Heritage | 1193 - 1194 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 5 6 7 Table 6.7 Barriers to climate adaptation Examples of barriers to climate adaptation Institutional changes to overcome those barriers Examples Evidence Lack of financial resources Strategic combination of municipal, regional and national level funds Access to multiple financing mechanisms In European countries, large cities tend to fund their own adaptation, while smaller settlements depend on regional or national funding (Aguiar et al., 2018) (Moser et al., 2019) Lack of human resources and capacities Development of formal and informal partnerships, cooperative agreements and inter�agency arrangements International cooperation programmes for adaptation in urban areas in the Global South are most likely to succeed if they can align their objectives with local priorities and capacities (UN-Habitat, 2016b) Political commitment and willingness to act Use of policy windows and extreme events to generate interest and create lasting responses In Germany, responses to flooding were strongly shaped by public perceptions of safety during the electoral cycle, leading to inadequate responses (Gawel et al., 2018; Di Giulio et al., 2018) Uncertainty about future impacts and dynamic interactions Develop institutional arrangements that acknowledge and reduce uncertainty Facilitate the development of bottom�up initiatives that relate directly to the context of action Power plant operators and the federal state of Baden-Württemberg negotiated the minimum power plant concept ("Mindestkraftwerkskonzept", MPP), a contract to establish more predictable and workable procedures for curtailment in the event of severe heat waves (Eisenack, 2016) (Thaler et al., 2019) Institutional fragmentation and unclear responsibilities Evaluation of existing institutions to diagnose miscoordination Creation of policy networks that address emerging interdependences In settlements in Languedoc, France, decentralisation adds complexity to the ongoing challenges of population growth and climate change (Therville et al., 2019) Legal issues and regulations Address the legal hurdles to create frameworks that allow for experimental action Policy makers in the San Francisco Bay Area, US reported that minor changes could have a definitive influence in delivering regulatory changes to support adaptation action In The Netherlands, a lack of climate change adaptation policy for cultural heritage hamper adaptation of cultural heritage to current and projected climate risks (Ekstrom and Moser, 2014) (Fatorić and Biesbroek, 2020) Competition of adaptation with other policy agendas and polarisation Prioritization and development of synergies across sectors Mainstreaming adaptation into other sectors In European cities, for example, urban planning is strongly correlated with water management strategies (Aguiar et al., 2018) (Sieber, Biesbroek and de Block, 2018) Lack of data, knowledge generation capacity, and knowledge exchange Mobilise multiple strategies for the use of climate information in local decision-making In Scotland, Hungary and Portugal local decision makers use HECC scenarios, but most often as background data (Lourenço et al., 2019) (Herrmann and Guenther, 2017) ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 6 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 6-85 Total pages: 183 Involve a wide range of stakeholders- with different values and knowledge- in decision making Sharing knowledge alongside the supply chain favours adaptation for both multinationals and SMEs (Gotgelf, Roggero and Eisenack, 2020) (Wamsler, 2017) 1 2 3 Institutional change, is needed to open new options for inclusive and sustainable adaptation and to integrate 4 adaptation and mitigation (robust evidence, high agreement) (see also Section 6.3.5). | Heritage | 1195 - 1196 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 31 Municipalities in Sweden have been called 'pre-reactive' because adequate strategic guidelines are in place 32 to frame the accessibility, aesthetics, and adaptability of waterfront developments (Storbjörk and Uggla, 33 2015). Some Asian cities also report high output effectiveness, where they are more likely to indicate senior 34 local government officials' performance management contracts, the budgeting procedures of local 35 government agencies, and the procedures that local government agencies use for budgeting infrastructure 36 spending (Aylett, 2015). Despite this evidence, there is a gap in understanding the general trends of planning 37 and institutional change in Africa, Asia, East Europe and the Middle East. | Heritage | 1197 - 1197 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 41 42 43 [START BOX 6.7 HERE] 44 45 Box 6.7: The Role of Urban Design in Local Adaptation 46 47 Since AR5 there has been a growing literature about the role of urban design, creating new opportunities for 48 both incremental and transformative adaptive responses to climate change (medium evidence, high 49 agreement). For example some of these creative design approaches compliment and extend regulatory and 50 land use planning approaches such as form-based codes and established certifications like LEED-ND 51 (Leadership in Energy and Environmental Design – Neighbourhood Design) (Garde, 2018; Garde and Hoff, 52 2017) and the USA's Sustainable Sites Initiative (SITES) (Valente, 2014). Emphasis on sufficiency has also 53 influenced urban design, for example, with the mobilization of 'doughnut' economics that emphasize both a 54 social foundation and an environmental ceiling, for example Amsterdam (Raworth, 2017). However, such 55 cases are rare, substantial public investment is often required (high confidence, high agreement) (see also 56 section 6.4.7 on finance and insurance). Other approaches underscore innovation and creativity, at the 57 essence of which are context-specific interventions that draw on a compendium of urban design principles ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 6 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 6-94 Total pages: 183 1 such as: indeterminacy (to accommodate climate uncertainty), polyvalency and diversity, and harmony with 2 nature (Dhar and Khirfan, 2017a). Creative interventions include the daylighting of buried streams to create 3 climate adaptive public realms (Khirfan et al., 2020; Khirfan, Mohtat and Peck, 2020). For example, the 4 demolition of a major expressway and the restoration of the Cheonggyecheon stream reorganised downtown 5 Seoul, South Korea and significantly contributed to climate change adaptation through stormwater 6 management and reducing the urban heat island effect (Kim and Jung, 2019). Biomimicry and ecological 7 infrastructure are design features that governance bodies can use to reshape space and contribute to place 8 making (Santos Nouri and Costa, 2017; Prior et al., 2018). For example, urban metabolism and local 9 ecological knowledge has constituted the essence of urban design interventions in the Island of Tobago in 10 ways that capitalize on the contiguous relationship between ecosystems (e.g., the mangrove forest) and 11 human actions (rainwater harvesting and grey water management) (Khirfan and Zhang, 2016). While lack of 12 funding, or design capacity, restrictive planning regulations, inequality and competing urban agendas can 13 create barriers for the implementation of creative design solutions, transition architecture movements are also 14 driving local urban adaptation experiments and exploring ways local learning can be scaled up (Tubridy, 15 2020; Irwin, 2019). | Heritage | 1204 - 1205 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 39 Paradigm changes, such as new engagements with nature and green infrastructure, will improve adaptation 40 outcomes (Roberts et al., 2012). Changes of paradigms, however, are not inherently positive and may clash 41 with existing interests or involve trade-offs with other priorities. When care is taken to ensure greater 42 inclusion in urban decision making, disadvantaged, vulnerable communities are less likely to be 43 disadvantaged. For example, indigenous traditions of nature management provide entry points for the 44 sustainable management of resources, such as seed banks, urban agriculture, and the local management of 45 watersheds and floods, may be at odds with conventional structures of expert knowledge (Cid-Aguayo, 2016; 46 Chandra and Gaganis, 2016). These traditions are vital both because of the solution space that they open in 47 the local context and how they serve to create resilience through collective and intergenerational learning 48 (Chandra and Gaganis, 2016). | Heritage | 1214 - 1214 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 54 55 The City of Semarang first engaged with climate change in 2009, when the Rockefeller Foundation launched 56 the Asian Cities Climate Change Resilience Network (ACCCRN), an initiative to develop resilience capacity 57 across secondary and rapidly growing cities in South and Southeast Asia (Reed et al., 2015). Semarang was a ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 6 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 6-107 Total pages: 183 1 pilot city for ACCCRN from 2009 to 2016, when it introduced a participatory approach to planning and 2 decision-making that challenged the government-dominated tradition in the city, and in turn played a key 3 role in Semarang's climate adaptation and resilience planning process (Orleans Reed et al., 2013; Moench, 4 2014; Kernaghan and Da Silva, 2014). A City Team was formed in 2010 consisting of City Environmental 5 Agency (BLH – Badan Lingkungan Hidup), Regional Disaster Management Agency (BPBD - Badan 6 Penanggulangan Bencana Daerah), Water Resources Management Office (PSDA - Kantor Dinas 7 Pengelolaan Sumber Daya Air), Regional Planning and Development Agency (BAPPEDA - Badan 8 Perencanaan Pembangunan Daerah), local universities, and NGOs such as the Bintari Foundation, with 9 technical support from Mercy Corps Indonesia (Nugraha and Lassa, 2018). | Heritage | 1217 - 1218 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 29 30 Xi'xian aims to build a 'modern garden city' when it was selected as national demonstration sites for Sponge 31 City (SC) during 2015-2018 and Climate Resilient City (CRC) during 2017-2020. Under the changing 32 climate, the old cities of Xi'xian suffers urban heat island, drying and water scarcity, heavy rains and 33 waterlogging, thunderstorm and so on, which bring adverse effects to transportation, construction, cultural 34 relics tourism resources, and other industries (Ma, Yan and Zeyu, 2021). Sponge City status requires 35 innovation to reduce flood risk through design to absorb, store, and purify rainfall and storm water in an 36 ecologically friendly way that reduces dangerous and polluted runoff. When required, the stored water is 37 released and added to the urban water supply (MoHURD, 2014). As Climate Resilient City the aim is to 38 adapt to climate risk and environmental change, by integrating climate resilience into urban renewal and 39 revitalization. | Heritage | 1219 - 1219 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 33 34 Efforts to adapt to climate change can be incremental, reformist, or transformational, depending on the scale 35 of the change required. Incremental action may address specific climate impacts in a given place, but do not 36 challenge the social and political institutions that prevent people from bouncing back better. Reformist action 37 may address some of the social and institutional drivers of exposure and vulnerability, but without 38 addressing the underlying socio-economic structures that drive differential forms of exposure. For example, 39 social protection measures may improve people's capacity to cope with climate impacts, but that improved 40 capacity will depend on maintaining such protection measures. Transformative action involves fundamental 41 changes in political and socio-economic systems, oriented towards addressing vulnerability drivers (e.g., 42 socio-economic inequalities, consumption cultures). All forms of adaptation are relevant to deliver resilient 43 futures because of the variability of conditions in which adaptation action is needed. | Heritage | 1231 - 1231 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 21 22 7.1.3.2 IPCC Special Reports 23 24 All three post-AR5 IPCC Special Reports considered some of the research that is assessed here in greater 25 detail. The 2018 report on 1.5° C (SR1.5) included a review of climate change and health literature published 26 since AR5 and called for further efforts for protecting health and wellbeing of vulnerable people and regions 27 (Ebi et al., 2018b), and highlighted links between climate change hazards, poverty, food security, migration, 28 and conflict. The 2019 Special Report on Climate Change and Land (SRCCL) (SRCCL, 2019) emphasized 29 the impacts of climate change on food security; highlighted links between reduced resilience of dryland 30 populations, land degradation migration, and conflict; and raised concerns about the impacts of climate 31 extremes. The 2019 Special Report on the Ocean and Cryosphere in a Changing Climate (Pörtner et al., 32 2019) detailed how changes in the cryosphere and ocean systems have impacted people and ecosystem 33 services, particularly food security, water resources, water quality, livelihoods, health and wellbeing, 34 infrastructure, transportation, tourism, and recreation, as well as the culture of human societies, particularly 35 for Indigenous peoples. It also noted the risks of future displacements due to rising sea levels and associated 36 coastal hazards. | Heritage | 1304 - 1304 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 48 49 There is no consensus definition of wellbeing, but it is generally agreed that it includes a predominance of 50 positive emotions and moods (e.g. happiness) compared with extreme negative emotions (e.g. anxiety), 51 satisfaction with life, a sense of meaning, and positive functioning, including the capacity for unimpaired 52 cognitive functioning and economic productivity (Diener and Tay, 2015) (Piekałkiewicz, 2017). A 53 capabilities approach (Sen, 2001) focuses on the opportunity for people to achieve their goals in life (Vik 54 and Carlquist, 2018) or the ability to take part in society in a meaningful way: the result of personal 55 freedoms, human agency, self-efficacy, an ability to self-actualize, dignity and relatedness to others 56 (Markussen et al., 2018). An Indigenous perspective on wellbeing is broad and typically incorporates a 57 healthy relationship with the natural world (Sangha et al., 2018); emotional and mental health have also been ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 7 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 7-11 Total pages: 181 1 linked to a strong cultural identity (Butler et al., 2019);(Dockery, 2020). "Health" itself is sometimes 2 described as including relationships between humans and nature as well as links to community and culture 3 (Donatuto et al., 2020);(Dudgeon et al., 2017) 4 5 Subjective wellbeing is consistently associated with personal indicators such as higher income, greater 6 economic productivity, better physical health (Diener and Tay, 2015);(Delhey and Dragolov, 2016);(De 7 Neve et al., 2013), and environmental health; and associated with societal indicators such as social cohesion 8 and equality (Delhey and Dragolov, 2016). In a global sample of over 1 million people obtained between 9 2004-2008 via the Gallup World Poll, annual income and access to food were strong predictors of subjective 10 wellbeing, and a healthy environment, particularly access to clean water, was also associated even when 11 household income was controlled (Diener and Tay, 2015). Access to green spaces is also associated with 12 wellbeing (high confidence) (Lovell et al., 2018);(Yuan et al., 2018). | Heritage | 1304 - 1305 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 7 8 7.1.7.3.6 Indigenous People 9 Indigenous Peoples, especially those that live in geographically isolated, resource-dependent, and/or 10 impoverished communities, are often at greater risk of health impacts of climate change (Ford et al., 2020) 11 (USGCRP, 2016). The close interconnection of land-based livelihoods and cultural identity of many 12 Indigenous groups exposes them to multiple health- and nutrition related hazards (Durkalec et al., 13 2015);(Sioui, 2019), with potential implications for community social relations and for individuals' mental 14 health (Cunsolo Willox et al., 2013);(Cunsolo Willox et al., 2015). Climate change risk exposures may be 15 complicated by changes in lifestyle, diet, and morbidity driven by socio-economic processes, further 16 increasing health risks for Indigenous peoples (Jaakkola et al., 2018). Environmental consequences of 17 climate change can also affect social ties and spiritual wellbeing, in part because land is often an integral part 18 of their culture and spiritual identity. | Heritage | 1310 - 1310 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 45 46 Tertiary effects relate to culture-wide changes; for example, all forms of malnutrition due to climate-driven 47 changes in food systems; and anxiety, mental illness, and suicidal thoughts related to cultural and spiritual 48 losses. A wide range of tertiary, culture-related effects of climate change have been documented for 49 Indigenous Peoples. These include anxiety, distress and other mental health impacts due to direct and 50 indirect processes of dispossession of land and culture related to the combination of climate change in and 51 other factors (Richmond and Ross, 2009);(Bowles, 2015);(Norton-Smith et al., 2016);(Jaakkola et al., 52 2018);(Fuentes et al., 2020);(Mamo, 2020);(Middleton et al., 2020b);(Middleton et al., 2020a);(Olson and 53 Metz, 2020);(Timlin et al., 2021). Increased risks of conflict and abuse, including violence and homicide 54 against females, and/or resulting from environment activism, are other tertiary health threats for Indigenous 55 Peoples (Mamo, 2020). Between 2017 and 2019, close to 500 Indigenous people were killed for activism in 56 19 different countries (Mamo, 2020). In Uganda, climate change drives Indigenous men to increase their ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 7 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 7-18 Total pages: 181 1 distance and time from home and their families in search of water, food, and water, leading to an increase in 2 sexual violence against Indigenous women and girls in their communities (Mamo, 2020). | Heritage | 1311 - 1312 |

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| Organisation | Document | Quotation Content | Codes | Page |
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| IPCC | IPCC_AR6_WGII_Full_ Report | 54 55 In a pilot project for climate adaptation of reindeer herding run by the Swedish Sami Parliament, reindeer 56 herding management plans (in Swedish, renbruksplaner) were used as a tool to develop strategies for climate 57 adaptation (Walkepää, 2019). Four Sami reindeer herding cooperatives participated in the pilot study. They ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 7 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 7-21 Total pages: 181 1 all agreed that climate change means that grazing patterns need to change. Traditionally, mountain reindeer 2 graze in the Scandinavian mountains close to Norway in summertime, and in the coastal areas close to the 3 Gulf of Bothnia in wintertime, representing a total migration route of up to 400 kilometres one-way. Rising 4 temperatures are causing spring to occur earlier in the coastal winter grazing land, before the calving areas in 5 the summer land are suitable for grazing and free from snow. When the snow cover disappears, the herds are 6 dispersed, so it is important to migrate while snow is still present (Walkepää, 2019). Migration routes are 7 being destabilized by weaker ice cover on water and by hazardous weather events. Competing land use due 8 to infrastructure, extractive industries, tourism, and energy production makes it difficult to find alternative 9 grazing land. Supplementary feeding and increased use of trucks to transport reindeer is one result. Herds 10 that are dispersed due to bad snow conditions have an increased exposure to predators (Walkepää, 2019 11 (Walkepää, 2019);(Uboni et al., 2020). By working strategically to secure adequate winter grazing and 12 reduce fragmentation of grazing areas more generally represents win-win strategies for achieving decreased 13 mental stress levels while reducing herders' consumption of fossil fuels (Walkepää, 2019). | Heritage | 1314 - 1315 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 40 sample, perceived ecological stress, defined as personal stress associated with environmental problems, 41 predicted depressive symptoms (Helm et al., 2018);in a sample of Filipinos, climate anxiety was correlated 42 with lower mental health (Reyes et al., 2021), and a non-random study in 25 countries showed positive 43 correlations between negative emotions about climate change and self-rated mental health (Ogunbode et al., 44 2021). However, an earlier study found no correlation between climate change worry and mental health 45 issues (Berry and Peel, 2015). Because the perceived threat of climate change is based on subjective 46 perceptions of risk and coping ability as well as on experiences and knowledge (Bradley et al., 2014), even 47 people who have not been directly affected may be stressed by a perception of looming danger (Clayton and 48 Karazsia, 2020). Not surprisingly, those who have directly experienced some of the effects of climate change 49 may be more likely to show such responses. Indigenous Peoples, whose culture and wellbeing tend to be 50 strongly linked to local environments, may be particularly likely to experience mental health effects 51 associated with changes in environmental risks; studies suggest connections to an increase in depression, 52 substance abuse, or suicide in some Indigenous Peoples (Canu et al., 2017);(Cunsolo Willox et al., 53 2013);(Middleton et al., 2020b);(Jaakkola et al., 2018). | Heritage | 1340 - 1340 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 54 55 7.2.5.2 Observed Impacts on Wellbeing 56 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 7 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 7-47 Total pages: 181 1 Overall, research suggests that climate change has already had negative effects on subjective wellbeing 2 (medium confidence). Climate change can affect wellbeing through a number of pathways, including loss of 3 access to green and blue spaces due to damage from storms, coastal erosion, drought, or wildfires; heat; 4 decreased air quality; and disruptions to one's normal pattern of behaviour, residence, occupation, or social 5 interactions (Hayward and Ayeb-Karlsson, 2021). For example, substantial evidence shows a negative 6 correlation between air pollution and subjective wellbeing or happiness (Apergis, 2018);(Cunado and de 7 Gracia, 2013);(Lu, 2020);(Luechinger, 2010);(Menz and Welsch, 2010);(Orru et al., 2016);(Yuan et al., 8 2018);(Zhang et al., 2017a); in the reverse direction, there is evidence not only that time in nature but more 9 specifically a feeling of connectedness to nature are both associated with wellbeing (Martin et al., 2020) and 10 healthy ecosystems offer opportunities for health improvements (Pretty and Barton, 2020). Negative 11 emotions such as grief - often termed 'solastalgia'(Albrecht et al., 2007) -- are associated with the 12 degradation of local or valued landscapes (Eisenman et al., 2015);(Ellis and Albrecht, 2017);(Polain et al., 13 2011);(Tschakert et al., 2017);(Tschakert et al., 2019), which may threaten cultural rituals, especially among 14 Indigenous Peoples (Cunsolo and Ellis, 2018);(Cunsolo et al., 2020). Studies conducted in the Solomon 15 Islands and in Tuvalu found qualitative and quantitative evidence of experiences of climate change and 16 worry about the future, with negative impacts on respondents' wellbeing (Asugeni et al., 2015);(Gibson et 17 al., 2020). | Heritage | 1340 - 1341 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 55 56 7.2.6 Observed Impacts on Migration 57 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 7 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 7-48 Total pages: 181 1 Consistent with peer-reviewed scholarship and with the UNFCCC Cancun Adaptation Framework section 2 14(f) and the Paris Agreement, this Chapter assesses the impacts of climate change on four types of 3 migration: 1) adaptive migration (i.e where migration is an outcome of individual or household choice ); (2) 4 involuntary displacement (i.e. where people have few or no options except to move); (3) organized 5 relocation of populations from sites highly exposed to climatic hazards; and (4) immobility (i.e. an inability 6 or unwillingness to move from areas of high exposure for cultural, economic or social reasons) (see Cross- 7 Chapter Box MIGRATE). | Heritage | 1341 - 1342 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 39 40 7.2.6.2 Immobility and Resettlement in the Context of Climatic Risks 41 42 Immobility in the context of climatic risks can reflect vulnerability and lack of agency (i.e., inability to 43 migrate), but can also be a deliberate choice (high confidence). Research since AR5 shows that immobility 44 is best described as a continuum, from people who are financially or physically unable to move away from 45 hazards (i.e. involuntary immobility) to people who choose not to move (i.e. voluntary immobility) because 46 of strong attachments to place, culture, and people (Nawrotzki and DeWaard, 2018); (Adams, 47 2016);(Farbotko and McMichael, 2019);(Zickgraf, 2019);(Neef et al., 2018);(Suckall et al., 2017);(Ayeb- 48 Karlsson et al., 2018);(Zickgraf, 2018);(Mallick and Schanze, 2020). Involuntary immobility is associated 49 with individuals and households with low adaptive capacity and high exposure to hazard and can exacerbate 50 inequality and future vulnerability to climate change (Sheller, 2018), including through impacts on health 51 (Schwerdtle et al., 2018). Voluntary immobility represents an assertion of the importance of culture, 52 livelihood and people to wellbeing, and is of particular relevance for Indigenous Peoples (Suliman et al., 53 2019). | Heritage | 1352 - 1352 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 5 6 Examples of relocations of small Indigenous communities in coastal Alaska and villages in the Solomon 7 Islands and Fiji suggest that relocated people can experience significant financial and emotional distress as 8 cultural and spiritual bonds to place and livelihoods are disrupted (Albert et al., 2018);(Neef et al., 9 2018);(McMichael and Katonivualiku, 2020);(McMichael and Katonivualiku, 2020);(McMichael et al., 10 2021);(Piggott-McKellar et al., 2019);(Bertana, 2020). Voluntary relocation programs offered by US state 11 governments in communities damaged by 2012's Hurricane Sandy have been subject to multiple studies, and 12 these show participants' longer term economic outcomes, social connections and mental wellbeing can 13 compare either favourably or unfavourably with non-participants for a range of reasons unrelated to the 14 impacts of the hazard event itself (Bukvic and Owen, 2017);(Binder et al., 2019);(Koslov and Merdjanoff, 15 2021), 16 17 18 [START BOX 7.4 HERE] 19 20 Box 7.4: Gender Dimensions of Climate-related Migration 21 22 Migration decision-making and outcomes – in both general terms and in response to climatic risks – are 23 strongly mediated by gender, social context, power dynamics, and human capital (Bhagat, 2017);(Singh and 24 Basu, 2020);(Rao et al., 2019a);(Ravera et al., 2016). Women tend to suffer disproportionately from the 25 negative impacts of extreme climate events for reasons ranging from caregiving responsibilities to lack of 26 control over household resources to cultural norms for attire (i.e. saris in South Asia) (Belay et al., 27 2017);(Jost et al., 2016). In many cultures, migrants are most often able-bodied, young men (Call et al., 28 2017);(Heaney and Winter, 2016). Women wait longer to migrate because of higher social costs and risks 29 (Evertsen and Van Der Geest, 2019) and barriers such as social structures, cultural practices, lack of 30 education, and reproductive roles (Belay et al., 2017);(Afriyie et al., 2018);(Evertsen and Van Der Geest, 31 2019)). | Heritage | 1353 - 1353 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 38 Nature-based solutions (NbS) to reduce heat that offer co-benefits for ecological systems include green and 39 blue infrastructure (e.g., urban greening/forestry and the creation of water bodies) (Koc et al., 2018);(Lai et 40 al., 2019);(Shooshtarian et al., 2018);(Ulpiani, 2019);(Zuvela-Aloise et al., 2016), (Hobbie and Grimm, 41 2020). The implementation of climate-sensitive design and planning can be constrained by governance 42 issues;(Jim et al., 2018) and the benefits are not always evenly distributed among residents. Implementation 43 of climate-sensitive design and NbS does, however, need to be carried out within the context of wider public 44 health planning because water bodies and moist vegetated surfaces provide suitable habitats for a range of 45 disease vectors;(Nasir et al., 2017);(Tian et al., 2016);(Trewin et al., 2020). Solutions recommended for 46 managing exposure to heat in outdoor workers include improved basic protection (including shade, planned 47 rest breaks), heat-appropriate personal protective equipment, work scheduling for cooler times of the day, 48 heat acclimation, improved aerobic fitness, access to sufficient cold drinking water, and on-site cooling 49 facilities and mechanisation of work (Morabito et al., 2021);(Morris et al., 2020);(Varghese et al., 50 2020);(Williams et al., 2020). | Heritage | 1385 - 1385 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 20 21 Because mental health is fundamentally intertwined with social and economic wellbeing, adaptation for 22 climate-related mental health risks benefits from wider multi-sectoral initiatives to enhance wellbeing, with 23 the potential for co-benefits to emerge (high confidence). Improvements in education, quality of housing, 24 safety, and social protection support enhance general wellbeing and make individuals more resilient to 25 climate risks (Lund et al., 2018);(Hayes et al., 2019). Among Indigenous Peoples, connections to traditional 26 culture and to place are associated with health and wellbeing (Bourke et al., 2018) as well as with resilience 27 to environmental change (Ford et al., 2020). As an example of the connection between infrastructure 28 improvements and mental health, a study of domestic rainwater harvesting initiatives to promote household 29 water security also improved mental health in participating households (Mercer and Hanrahan, 2017). | Heritage | 1392 - 1392 |

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| IPCC | IPCC_AR6_WGII_Full_Report | information incorporated as convenient; occasional partnerships Proactive; adaptively managed; frequent partnerships; interdisciplinary Leadership and governance Little focus at national and international levels on climate change and health; minimal planning conducted Planning on climate change and health, but not comprehensive and often side�tracked on other issues Strong climate change and health planning apparatus, including health components of national adaptation plans; regional / international partnerships Health workforce Climate change and health not rarely incorporated into training; few provisions for new training programs or funding for increase health worker positions in climate change-relevant specialties; health disparities not addressed Climate change and health not systematically incorporated into training; new training programs insufficient to fill gaps in demand; limited attention to addressing health disparities Systematic inclusion of climate change and health in worker training; expansion of funding and training; financing and incentive mechanisms to address health disparities ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 7 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 7-111 Total pages: 181 Health information systems Assessments of vulnerability and adaptation rarely, if ever conducted; information not useful for planning; minimal risk monitoring or research Vulnerability and adaptation assessments occasionally conducted, but generally of poor quality; early warnings incomplete; fiscal and political constraints on research Vulnerability and adaptation assessments regularly conducted and used in planning; robust early warning networks; research agenda focused on vulnerable communities Climate resilient and sustainable technologies and infrastructure Facilities sited and constructed without climate consideration incorporated; medical supply chains no modified Capital cost serves as key factor in siting and construction; increasing vulnerability of facilities to shocks Health infrastructure designed to be robust to storms/floods, with redundant systems added to ensure continuity of care Service delivery Policies to manage environmental health hazards generally not followed; care practices not modified to accommodate climate information; few changes to emergency management procedures; health inequities worsen Environmental health policies are not robust; marginal improvements in care practices; risk assessments and communication inadequate; no shift in health inequities Policies to manage environmental health hazards regularly reviewed; practitioners review care practices and adjust as appropriate based on local climate and health conditions; robust communication tools developed; health service improvements reduce health inequities Climate and health financing Few funds devoted to climate change and health activities, particularly in low- and middle-income countries; few if any financing partnerships between high- and low- and middle-income countries; very weak regional and international coordinating bodies due to funding constraints High-income countries generally form robust financing mechanisms; fiscal pressures in low- and middle-income countries constrain their financing abilities; financial partnerships formed across countries, but financing often not robust; regional and international coordinating bodies receive inadequate funds Robust funding streams for climate change and health; climate change and health activities receive continuing financial support; effective financing partnerships; regional and international coordinating bodies effectively funded 1 2 3 Stress testing is an approach for evaluating the extent to which health systems are prepared for a future 4 different from today (Ebi et al., 2018a). These desk-based exercises identify a desirable future outcome, such 5 as successfully managing an extreme heatwave, flood, or storm with characteristics outside the range of 6 recent experiences. The exercises move beyond identifying likely challenges from hazardous exposures to 7 specifying policies and measures that could be successful under a different climate and development 8 pathway. The exercises consider socioeconomic and political factors that can influence the extent of health 9 system vulnerability and factors that can affect health system demands by impacting population health. | Heritage | 1404 - 1405 |
| IPCC | IPCC_AR6_WGII_Full_Report | 7 8 Shifting to sustainable food systems that provide affordable diverse plant-rich diets with moderate quantities 9 of GHG-intensive animal protein can bring health co-benefits and substantially reduce GHG emissions, 10 especially in high income countries and where ill health related to overconsumption of animal-based 11 products is prevalent (very high confidence). {5.12.6, WGII} {7.4, 13.5, WGII} {5.WGIII} (7.4 WGIII) 12 (Springmann et al., 2018c);(SRCCL, 2019); (Clark and Tilman, 2017); (Poore and Nemecek, 2018); (Hayek 13 et al., 2021). Transforming the food system by limiting the demand for GHG-intensive animal foods, 14 reducing food over-consumption and transitioning to nutritious, plant-rich diets, can have significant co- 15 benefits to health (high confidence) (Hedenus et al., 2014); (Ripple et al., 2014);(Tirado, 2017); (Springmann 16 et al., 2018c); IPCC SR1.5, 2018). (SROC 2019).(SRCCL, 2019); (Nelson et al., 2016); (Willett et al., 17 2019);(Tilman and Clark, 2014);(Green et al., 2015);(Springmann et al., 2016b);(Springmann et al., 18 2018b);(Springmann et al., 2018a);(Springmann et al., 2018c); (Milner et al., 2015);(Milner et al., 19 2017);(Farchi et al., 2017);(Song et al., 2017); (Willett et al., 2019). Reduction of red meat consumption 20 reduces the risk of cardiovascular disease and colorectal cancer; and the consumption of more fruits and 21 vegetables can reduce the risk of cardiovascular disease, type II diabetes, cancer, and all causes of mortality 22 (WHO, 2015c);(Tilman and Clark, 2014);(Sabate and Soret, 2014); (Willett et al., 2019). {7.4 WGIII} 23 {5.12.5 WGII} {6.3 WGIII}. Globally, it is estimated that transitioning to more plant-based diets - in line 24 with WHO recommendations on healthy eating - could reduce global mortality by 6–10% and food-related 25 greenhouse gas emissions by 29–70% by 2050 (Springmann et al., 2016b). There are limitations in 26 accessibility of affordable of healthy and diverse diets for all (Springmann et al., 2020) and trade-offs such 27 as the potential increase of GHG emissions from producing healthy and diverse diets in low- and medium- 28 income countries (Semba et al. 2020). Agroecological approaches have mitigation and adaptation potential, 29 deliver ecosystem services, biodiversity, livelihoods and benefits to nutrition, health, and equity (Rosenstock 30 et al., 2019);(Bezner Kerr et al., 2021);{5.4.4; 5.14.1 WGII} {13.5, 14.4.4 WGII}. | Heritage | 1409 - 1409 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 24 25 [END BOX 8.1 HERE] 26 27 28 8.2.1.6 Interactions between climate hazards and social-ecological thresholds 29 30 Climate change threatens to rapidly transform unique and threatened ecosystems (RFC1), such as tropical 31 rain forests, coral reefs, arctic and high-mountain ecosystems, as well as the Indigenous and forest-dwelling 32 people whose livelihoods, cultures and identities are dependent on these ecosystems. In recent years, the case 33 of Amazonia illustrates how such systems are transforming, with detrimental consequences for Indigenous 34 Peoples, and the vital role that Indigenous Peoples serve in protecting vulnerable ecosystems (Ricketts et al., 35 2010; Box 8.6). Globally, Indigenous territories cover the greatest area of remaining tropical forest in 36 comparison to other protected areas, and encompass the bulk of Earth's biodiversity, and are the locus for a 37 number of key ecosystem services across spatial and temporal scales(Walker et al., 2020). Specifically, in 38 2014 Indigenous territories and other protected areas represented the equivalent of 58.5% of all the carbon 39 stored in the Brazilian Amazon biome and had the lowest deforestation rate (2.1%) and fire incidences, 40 evidencing the effectiveness in safeguarding important ecosystems services and wellbeing (Nogueira et al., 41 2018). It is estimated that Indigenous territories in the Brazilian Amazon contribute at least US$5 billion 42 each year to the global economy through food and energy production, greenhouse emissions offsets, and 43 climate regulation and stability (Siqueira-Gay et al., 2020). Given the high incidence of poverty of the 44 Amazonian countries and high proportion of traditional and Indigenous Peoples, remoteness and neglected 45 governance place these unique ecosystems and Indigenous populations as highly vulnerable to climate 46 change impacts (Pinho et al., 2014; Brondízio et al., 2016; Mansur et al., 2016; Kasecker et al., 2018). | Heritage | 1492 - 1492 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 55 56 Overall, this case study illustrates the benefits of promoting resilient crop production in Gargey Village, as 57 an example of displaced atoll communities. Innovative and sustainable CSA strategies offered broader ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 8 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 8-20 Total pages: 155 1 insights and lessons for enhancing adaptive capacity and resilience, on a degraded landscape. The coherent 2 strategies and methods employed strengthened livelihood opportunities by improving access to services, 3 knowledge, and resources. By its concurrent focus on enhancing food security through traditional crops, 4 coupled with nutrient-rich vegetables, promoting rainwater-harvesting systems and water conservation, and 5 promoting resilient household livelihood opportunities, atoll communities brought together crucial elements 6 needed to reduce vulnerabilities, and to better cope with disasters and climate extremes while embracing the 7 traditional culture. The location-specific yet knowledge-intensive CSA methods deployed, offered 8 opportunities for atoll communities to revitalize themselves, overcoming barriers while adjusting to new 9 landscapes. | Heritage | 1494 - 1495 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 29 Climate change impacts can also heighten existing gender inequalities (Jost et al., 2016; Glazebrook et al., 30 2020). On the one hand, climate change impacts can be gendered as a result of customary roles in society, 31 such as triple workloads for women (i.e., economic labour, household and family labour as well as duties of 32 community participation), and occupational hazards from gendered work indoors and outdoors (Murray et 33 al., 2016). On the other, climate change hazards interact with changing gender roles in society, such as urban 34 migration of both men and women in ways that break with tradition (Bhatta et al., 2016). | Heritage | 1502 - 1502 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 23 24 Impacts of climate change are affecting the economic and non-economic dimensions of people's lives, 25 including subsistence practices of communities that are experiencing decreases in agriculture productivity 26 and quality, water stress, increases in pests and diseases, disruption to culture, and emotional and 27 psychological distress, just to cite a few (Savo et al., 2016). For example, the cumulative effects of slow- 28 onset events threaten food security especially among the poor in Latin America and the Caribbean—regions 29 which face the largest gender gap in terms of food security globally (Zuñiga et al., 2021). In general for 30 Global South countries, the global average temperature warming (including the Paris target of 1.5°C) means 31 substantially higher warming and including higher frequency and magnitude of extreme events, that will 32 result in significant impacts on societal vulnerability (Aitsi-Selmi and Murray, 2016; Djalante, 2019). | Heritage | 1519 - 1519 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 5 6 A pertinent example of economic losses is the example of the Torres Strait in Australia. This example shows 7 evidence of communities living on remote islands Boigu, a low-lying mud island inundated by the sea during 8 high tides and storm surges, and those most exposed and vulnerable to climate change have limited 9 livelihood assets and face challenges to secure external support with government and others. Place-based 10 values evoke a reluctance to relocate or retreat with economic losses such as community infrastructure, 11 housing, and cultural sites (McNamara et al., 2017). In the Great Barrier Reef, Australia sea level rise and 12 sea level global temperature warming affects fisheries productivity and tourism (Evans et al., 2016). | Heritage | 1521 - 1521 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 26 27 Extreme climate events are disproportionately impacting economies of the most vulnerable everywhere 28 (medium evidence, high agreement). In the United States, Central America and Caribbean, Hurricanes 29 Katrina, Harvey, Irma, Maria and Michael are examples of extreme climate events that have displaced 30 households, destroyed homes, and led to loss of income among the poor and marginalized (Klinenberg et al., 31 2020). Puerto Rico was devastated by Maria but received less support from the Federal Emergency 32 Management Agency (FEMA) (García, 2021). Evidence is emerging on unequal governance response in the 33 US versus Puerto Rico (Joseph et al., 2020). Floods, storms and heatwaves have impacted the poorer 34 communities, and even wildfires in California, impact many wealthy groups, also impacted infrastructure 35 used by all, for example, with lengthy electrical power blackouts, but particularly impacted vulnerable to 36 disasters such as undocumented Latino/a and Indigenous immigrants in the case of the Thomas Fire in 37 California's Ventura and Santa Barbara counties(Méndez et al., 2020) Hurricane Irma in 2017 hit Ragged 38 Island in the Bahamas as a category 5 storm leaving the island in ruins and deemed 'unlivable' by its 39 authorities, with most infrastructure left as rubble, no essential utilities remained, schools and health clinics 40 were in ruins and the stench of dead animals was overwhelming. This storm resulted in signiffcant economic 41 loss and damage by the community through loss of their homes, churches, schools, agricultural land, and 42 infrastructure (Thomas and Benjamin, 2020). | Heritage | 1521 - 1521 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 20 21 Non-economic loss and damage (NELD) is values based (subjective and intangible) and relates to norms, 22 social values and highlights intersectional experiences and perspectives on climate risk. The discourse on 23 loss and damage includes a framing of NELD as loss of human and non-human life and mental and physical 24 health and are experienced widely across the world in vastly different ways associated with social values 25 (Tschakert et al., 2019). There are respectable arguments for the case that all life has intrinsic value 26 (Vetlesen, 2019). The NELD framing of climate impacts highlights that not all risks are measurable. While 27 difficult to measure, there are a growing number of cases of non-economic loss and damage globally 28 (medium evidence, high agreement). Illustrative examples of non-economic loss and damage from climate 29 change include the Pacific (McNamara et al., 2021b) and Small Island Developing States (SIDS) in the 30 Caribbean. (Martyr-Koller et al., 2021). For example, the hurricane season in 2017 was particularly extreme 31 resulting in climate-induced displacement with direct implications for non-economic loss and damage, 32 including threats to health and wellbeing and loss of culture and agency (Thomas and Benjamin, 2020). | Heritage | 1522 - 1522 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 33 34 In the context of the Pacific Islands NELDs are thought of as interconnected and span human mobility and 35 territory, cultural heritage and Indigenous Knowledge, life and health, biodiversity and ecosystem services, 36 and sense of place and social cohesion (Carmona et al., 2017; Ojwang et al., 2017; McNamara et al., 2021b). | Heritage | 1522 - 1522 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 49 50 In order to categorise the different types of non-economic loss and damage that exist (Serdeczny et al., 51 2016), based on their literature review, the authors come up with a set of systematic categories that capture 52 what is usually thought about as having intrinsic value and according this framing of non-economic loss and 53 damage this includes: human life, sense of place and mobility, cultural artefacts, biodiversity and 54 ecosystems, communal and production sites and agency and identity (Serdeczny et al., 2016; Serdeczny, 55 2019). For example, there is emerging evidence on linkages between slow onset events and mobility 56 decisions, trajectories and outcomes (Zickgraf, 2021). In addition, categories include psychosocial and 57 emotional distress (van Der Geest and Schindler, 2016). For example, research shows potential increased ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 8 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 8-48 Total pages: 155 1 risk of Intimate Partner Violence (IPV) following disasters, noting that societies that are vulnerable to 2 climate change may need to prepare for the social disasters that can accompany disasters revealed by natural 3 hazards (Malik and Stolove, 2017; Rai et al., 2021). | Heritage | 1522 - 1523 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 7 Key groups affected include low income groups, agropastoralists, women and girls, children and youth, 8 Indigenous Peoples, ethnic and religious minorities. In Europe, the Samis who as a group face significant 9 challenges to health as ecosystems deteriorate (Jaakkola et al., 2018). In Africa, In Zimbabwe storm Idai 10 affected 270,000 people and subsequent flooding and landslides left 340 people dead and many others 11 missing (Chanza et al., 2020). There is evidence of loss of cultural heritage sites where effects of sea-level 12 rise and coastal erosion, the other considering climate change and variability (Brooks et al., 2020). Haile et 13 al. (2013) show flood casualties in Ethiopia include children drowned while playing outside during the 2007 14 flood period although official data is hard to come by (p. 489). Moreover, loss of place was experienced 15 when many of local houses in Itang built from wood, grasses and mud walls, which are easy to reconstruct 16 building economics are not strong enough to withstand an extreme flood and 38% of the surveyed houses 17 were severely damaged by the 2007 flood. These houses were constructed as an adaptation strategy but could 18 not withstand the floods. In Kenya, Opondo (2013) shows loss of human life was the most severe impact of 19 floods. For example, in the focus group discussion with men, 'it was reported that a boat capsized on River 20 Nzoia at Siginga and ten people died'. (p. 457). In Mozambique, Brida et al. (2013) show loss of sense of 21 place occurred after flooding in the central districts of Caia and Mopeia, flooding had a devastating impact 22 on homes and livestock (Brida et al., 2013). Health impacts of the forest fire impacts in Amazon basin 23 countries have disproportionately affected vulnerable people/social groups (see Box 8.6). | Heritage | 1523 - 1523 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 5 6 8.3.5 Economic and non-economic losses and damages due to climate change and their implications for 7 livelihoods and livelihood shifts 8 9 This section examines the intersections between losses and damages and livelihood shifts. This requires an 10 examination of the differentiated aspects of livelihoods. Understanding economic (e.g., loss of food crops, 11 infrastructure, assets etc.) and non-economic losses (e.g., health, wellbeing, loss of place, agency) and their 12 consequences for livelihoods is important that the intangible aspects clearly become visible and to receive 13 greater attention in loss assessments and in designing adaptation strategies and programmes. Figure 8.10 14 provides a summary of examples of observed impacts of climate hazards on economic and non-economic 15 capitals and the section assesses livelihood implications across regions. It shows examples of climate hazards 16 attributed to climate change in studies since AR5, across a range of geographical sites for heatwaves, 17 drought, hurricanes, and floods and non-economic losses and damages. The figure 8.10 reveals examples of 18 climate hazards attributed to climate change in studies since AR5 across a range of geographical sites for 19 extreme and slow onset events, such as heatwaves, drought, hurricanes and sea level rise. These are 20 associated with non-economic losses and damages. These figure underscores that non-economic losses and 21 damages lead to significant livelihood threats and livelihood changes. Also limits of adaptation become 22 evident (Chapter 16). | Heritage | 1524 - 1524 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 40 41 In Central Asia, the Sahel and South Asia, three global poverty hotspots, change impacts were shown to 42 undermine traditional knowledge about livelihoods in ways that jeopardise future culture cohesion and sense 43 of place (Tucker et al., 2015). Acosta et al. (2016) identified loss to productive sites in the Philippines with 44 landslides destroying agriculture leaving many farmers without livelihoods. Similarly, Beckman and Nguyen 45 (2016) in Vietnam identified an example where communal dams had been destroyed in floods leading to lack 46 of irrigation for communal sites and local loss of farmland for farming communities. Chandra et al. (2017) 47 identified the vicious cycle between declining agricultural production and conditions of soil erosion due to 48 floods and droughts resulting in decreased crop fertility to productive sites with implications for decline in 49 crop yields, loss of crops and of livelihood assets. Climate change related extreme weather events such as 50 typhoons, floods, and droughts can have detrimental impacts on crop production (high confidence) and in the 51 Philippines and Pakistan have significantly affected the livelihoods of cash crop focused rural villages 52 (Escarcha et al., 2020; Jamshed et al., 2020b). There is an emerging shift from crop to livestock production 53 as a buffer activity to recover from crop losses (Section 5.10.4; Jamshed et al., 2017; Escarcha et al., 2020). | Heritage | 1526 - 1526 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 13 14 Research from Australia shows complex linkages between the impacts of drought on livelihood income, 15 health and cultural heritage, increasing risk of heat stroke, and possibly a link to suicide among male farmers 16 (Alston, 2012; Hanigan et al., 2012; Marshall et al., 2019). The link between agricultural losses and suicides 17 has also been noted in South Asia, including India (Carleton, 2017). Livelihoods are shifting with impacts to 18 wellbeing, as noted by (Evans et al., 2016) showing connections between loss of fishery productivity and 19 impact on tourism sector livelihoods in the Great Barrier Reef region. In Europe, losses to Indigenous 20 Peoples are associated with loss of wellbeing of Sami communities and has forced livelihood shifts from 21 reindeer herding due to loss of ecosystems to support the animals (Persson et al., 2017; Jaakkola et al., 22 2018). Traditional pastoralist systems are also greatly impacted by cumulative dual challenges of 23 encroachments of other land users and by climate change. Traditional Sami reindeer herding strategies are 24 still practiced, but that rapidly changing environmental circumstances are forcing herders into uncharted 25 territories where traditional strategies and the transmission of knowledge between generations may be of 26 limited use. For example, rotational grazing is no longer possible as all pastures are being used, and changes 27 in climate result in unpredictable weather patterns unknown to earlier generations (Axelsson-Linkowski et 28 al., 2020). These examples show that there are complex factors underpinning the linking loss and damage 29 and shifting livelihoods. Moreover, there are significant challenges to undertake a shift and secure alternative 30 livelihoods. | Heritage | 1527 - 1527 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 31 32 Linkages between losses, coping strategies and livelihood shifts in Small Islands (e.g., in the Pacific region 33 Kiribati and Tuvalu, and in the Caribbean the Bahamas) shed light on impacted low-income households. For 34 example, farmers have experienced extensive damage to homes and loss of infrastructure, and experience 35 lack of migration opportunities (Curtain and Dornan, 2019). Evidence is growing that there is also significant 36 loss of cultural heritage in resettlement (Barnett and O'neill, 2012), evidence from Small Islands displaced 37 communities suggests that resettlement can have impacts on sense of place, identity and social fabric, a 38 theme highly relevant to loss, coping and adapting livelihoods, and not only restricted to Small Islands 39 (McNamara et al., 2021b). Roberts (2015) identified loss of communal sites in Kiribati and it is predicted 40 that by 2050 up to 80% of the land on the island of Buariki and 50% of the land on Bikenibeu may be 41 completely inundated and these effects will result in significant loss of livelihoods and displacement. | Heritage | 1527 - 1527 |

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| Organisation | Document | Quotation Content | Codes | Page |
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| IPCC | IPCC_AR6_WGII_Full_Report | 51 Across Peru, findings demonstrate that people use temporary and permanent migration among their many 52 coping and adaptation strategies. Hazards related to water excess have been the key force in destroying 53 homes and driving displacement in Peru. On the flipside, studies demonstrate that water scarcity also 54 threatens livelihoods and thereby influences migration in Peru. While non-climatic reasons for moving 55 dominate migrants' motivations in many areas of Peru, water-related climatic drivers of migration are 56 becoming increasingly relevant (Wrathall et al., 2014). Peru's smallholder farmers and urban poor are not 57 responsible for the climate crisis, yet their lives and cultural heritage are being increasingly jeopardized by ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 8 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 8-53 Total pages: 155 1 its effects, making improvements in governance an imperative for Peru (Bergmann et al., 2021). Another 2 area of significance is coffee production in Brazil where the majority of Brazilian coffee farms are operated 3 by smallholders, producers with relatively small properties and mostly reliant on family labour (Koh et al., 4 2020). In the United States (e.g., New Orleans and Puerto Rico) people have lost livelihoods due to displaced 5 households, destroyed homes, and led to loss of income as well as loss of social networks and family 6 networks and loss of cultural heritage. For example, impacts of Hurricane Katrina have led to people being 7 displaced from their employment, many evacuees had to relocate to new areas, which disrupted their social 8 networks and placed them in unfamiliar labour markets, resulting in mental health challenges (Palinkas, 9 2020). There has also been a 'climate gentrification' in parts of New Orleans (Aune et al., 2020). Many of 10 those who returned to their pre-Katrina areas had to deal with extensive damage to their homes and to public 11 infrastructure. | Heritage | 1527 - 1528 |
| IPCC | IPCC_AR6_WGII_Full_Report | 57 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 8 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 8-54 Total pages: 155 1 These 'climate gating' actions, such as drilling boreholes, secured water access for high-income households 2 and companies, but excluded a large proportion of Cape Town's population who could not afford such 3 private technologies (Simpson et al., 2019a; Simpson et al., 2020b). These responses were unanticipated by 4 the city administration and compounded fiscal challenges faced by the municipality which could no longer 5 use revenues from high-consumption households to cross-subsidise water for low-income households 6 (Simpson et al., 2020a). This shift threatened to undermine the sustainability of the municipal fiscus and 7 general water access ( Box 9.8; Simpson et al., 2019a; Simpson et al., 2020a). In order to recover losses, 8 municipal water tariffs for consumers were raised by 26% in 2018 (Muller, 2018; Simpson et al., 2019a). In 9 addition to decline in tourism, median estimations of the overall economic impact of the drought indicate 10 loss of 27.6 billion South African Rand (US$1.7 billion) translating into 64,810 job losses in the Western 11 Cape, with Cape Town accounting for approximately half of those job losses (DEDAT, 2018). This had a 12 disproportionate impact on unskilled and semi-skilled workers, particularly for those from low- and middle- 13 income households (DEDAT, 2018). The drought also exacerbated the potential for sanitation health risks of 14 the urban poor where tens of thousands of people lack access to safely managed sanitation facilities (Enqvist 15 and Ziervogel, 2019). | Heritage | 1528 - 1529 |
| IPCC | IPCC_AR6_WGII_Full_Report | 50 51 8.4.3 The influence of climate change responses on projected development pathways 52 53 Responses to climate change can have dual effects on development pathways. On the one hand, mitigation 54 and adaptation processes can create significant development opportunities. The potential of mitigation 55 policies for jobs creation, in particular, has been highlighted (Healy and Barry, 2017). However, responses to 56 climate change can also have detrimental effects on future development: mitigation policies such as the 57 building of hydro-electrical dams or the culture of biofuels can lead to communities' dislocation and ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 8 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 8-58 Total pages: 155 1 populations' resettlement, particularly of disadvantaged groups within a society (de Sherbinin et al., 2011; 2 Eriksen et al., 2021). Adaptation policies can also hinder some development processes: for example, the 3 promotion of migration as an adaptation strategy can lead to communities being deprived of their workforce, 4 and resenting the departure of some of their members (Gemenne and Blocher, 2017), even though they may 5 offer new livelihood opportunities. However, the migration consequences in the context of climate change 6 are often more nuanced and different trade-offs and benefits occur (see Porst and Sakdapolrak, 2020). For 7 example, remittances support family members, at the same time in some cases these can also create 8 imbalances in local markets (Melde et al., 2017). Evidence exists that some climate responses such as small- 9 scale agricultural livelihood adaptation strategies have improved the ability of people to sustain their 10 livelihood and to reduce poverty (Osbahr et al., 2010). | Heritage | 1532 - 1533 |

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| IPCC | IPCC_AR6_WGII_Full_Report | 36 37 8.4.5 Projected risks for livelihoods and consequences for equity and sustainability 38 39 8.4.5.1 Projected risks for livelihoods 40 41 There is robust evidence with high agreement that future climate change impacts will have severe 42 consequences for poor households, particularly those situated in areas highly exposed to actual or future 43 climate hazards, such as low lying coastal communities (see also Cross-Chapter Paper 1 COASTS), drylands 44 (see also Cross-Chapter Paper 3 DRYLANDS) or remote mountain (see also Cross-Chapter Paper 5 45 MOUNTAINS) settlements with low levels of connectivity to markets, poor infrastructure and high 46 dependence upon poor quality natural capital (Barbier and Hochard, 2018; Gioli et al., 2019). While 47 livelihoods operate in a dynamic context characterised by multiple interacting structures and processes, 48 climate change can act as a risk multiplier. When current livelihood activities become untenable as a result of 49 both long trends and short-term shocks and climate hazards (e.g., droughts, floods), shifting livelihoods is a 50 common response and in many cases can be unavoidable due to the negative consequences of these climate 51 hazards on specific livelihood capitals (see Section 8.5). Such shifts can involve a change in livelihood 52 activities (e.g., continuing in agriculture but growing different kinds of crops), or a change to broader 53 livelihood strategies (e.g., diversifying into handicrafts or paid employment, specialising in one particular 54 activity, or migrating, seasonally or permanently in search of other livelihood opportunities) or even an 55 entire change of the livelihood activity, for example, abandoning agriculture altogether (McLeman and Smit, 56 2006; Black et al., 2011). Shifting livelihoods can therefore involve mobility or take place in situ. Some of 57 these shifts also lead to social tipping points. | Heritage | 1534 - 1534 |
| IPCC | IPCC_AR6_WGII_Full_Report | 15 16 In the Arctic, temperature warming, and sea level rising constitute a key risk to the loss of identity and 17 culture of Indigenous People, associated to migration and or relocation due to livelihoods deterioration from 18 coastal erosion, permafrost thaw, and reduced fisheries productivity (Roberts and Andrei, 2015; Roy et al., 19 2018). These risks and losses often encompass various non-economic losses, such as the loss of identity that 20 cannot be replaced or economically compensated (see also Section 8.3.5). | Heritage | 1539 - 1539 |
| IPCC | IPCC_AR6_WGII_Full_Report | 33 34 The glacier retreat associated with the increase in global warming temperature has also shown losses that are 35 permanent and related to a sense of belonging and cultural heritage for the Glacier countries but with the 36 most negative livelihood impacts experienced among poor households in the Peruvian Andes and Himalayas 37 (Jurt et al., 2015). The risks for the glacier smallholder's livelihoods are expected to increase in the future 38 once the shrinking glaciers are expected to increase water competition, crop failure, and extreme flooding 39 (Kraaijenbrink et al., 2017). For example, in Bhutan adaptive measures such as changing crops, developing 40 irrigation channels, and sharing water among the community members still insufficient to avoid loss and 41 damage associated with the dramatically reduced water availability (Kusters and Wangdi, 2013; Warner and 42 Van der Geest, 2013). In high Mountain Regions, the intersections of agro-pastoralists marginalization, 43 difficult in access, and ecological sensitivity contribute to residual impacts associated with extreme climate 44 hazards which can lead to irreversible losses and challenge poverty reduction efforts (Mishra et al., 2019). | Heritage | 1539 - 1539 |
| IPCC | IPCC_AR6_WGII_Full_Report | 42 43 Fires are not a natural phenomenon in the Amazon region (Bush et al., 2004; McMichael et al., 2012) albeit 44 used for food security, hunting and religious rituals among Indigenous Peoples and traditional communities 45 (Hecht, 2006; Carmenta et al., 2019; da Cunha, 2020), and also as a widespread technique for land clearing 46 for small and large-scale farms for agriculture (Morello et al., 2019). The dramatically increased forest 47 burning observed in the Amazon recently are the results of illegal land grabbing, the small and large-scale 48 cattle ranching sector and agribusiness practices coupled with loosening land tenure policies and decision 49 making neglect of deforestation and burning monitoring data (Nobre et al., 2016; Lovejoy and Nobre, 2018; 50 Leal Filho et al., 2020a). The fire outbreaks intensified substantially to the point that in August 2019 there 51 were approximately 3500 fires in 148 Indigenous territories (DETER and INPE, 2019; ISA, 2019). Although 52 most of the burning in the Legal Amazon in Brazil occurred on private land of medium and larger sizes 53 (about 67%), around 33% was observed within Indigenous territories and protected areas called conservation 54 units (UCs) (DETER and INPE, 2019; ISA, 2019). In 2019, 40% of the deforestation occurred in public 55 forests, which encompasses undesignated forest lands, Indigenous territories and conservation units (UCs). | Heritage | 1540 - 1540 |
| IPCC | IPCC_AR6_WGII_Full_Report | 23 24 In the Acre State, the fire incidence coupled with extreme droughts in 2005 and 2010 led to an increase— 25 from 1.2% to 27%—in hospitalizations of children (under 5 years) due to respiratory diseases (Smith et al., 26 2015). The same evidence was found among the rapidly deforested areas known as 'Arc of Deforestation' 27 that have dramatically led to a higher number of respiratory diseases mainly in children under 5 years (do 28 Carmo et al., 2013). There is also evidence for interlinked dynamics between deforestation, urbanization and 29 incidence of fire episodes providing an appropriate environment for Anopheles darlingi vector propagation 30 and the increased incidence of malaria in the region (Hahn et al., 2014). In the 2005 drought, burning in Acre 31 alone recorded 400,000 people affected and the loss of 300,000 hectares of forest with direct costs of US$50 32 million (Brown et al., 2006). In 2010, the fires during the drought were approximately 16 times larger than 33 that in the meteorologically normal years (Campanharo et al., 2019). The estimated total economic loss in 34 2010 was about US$243.36 ± 85.05 million, representing 9.07 ± 2.46% of Acre's gross domestic product 35 (GDP) (Campanharo et al., 2019). The economic and non-economic losses associated with the impacts of 36 climate change and future risks of fires outbreaks on native food crops (açai, guaraná), livelihoods, tourism, 37 medicinal and spiritual sites, culture, migration patterns, place-based attachments, emotional and mental 38 distress among the most affected and vulnerable population as Indigenous Peoples and traditional 39 communities are still to be fully estimated for the region (Pinho et al., 2015; Brondízio et al., 2016). Also 40 relevant is a trend of Amazonian forest fires spreading from the southern Brazilian Amazon to Bolivia and 41 Peru, indicating that transboundary burning increases are systemic and will lead to extensive economic 42 losses of wildcrops, infrastructure and livelihoods, and requiring a landscape level approach for deforestation 43 and fire management and control (Kalamandeen et al., 2018). | Heritage | 1541 - 1541 |

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| IPCC | IPCC_AR6_WGII_Full_Report | 26 27 Table 8.6, built from SR1.5°C (Roy et al., 2018), illustrates how ecological thresholds and socio-economic 28 determinants are linked to soft and hard adaptation limits and what are the potential and magnitude of 29 livelihoods risks in the future. For instance, in the SR1.5°C (IPCC, 2018b) and SROCC (IPCC, 2019b), hard 30 limits are expected with global warming beyond 1.5°C associated with the losses of coral reefs, that will lead 31 to substantial loss of income and livelihoods for coastal communities (Roy et al., 2018; Mechler et al., 32 2019b; Oppenheimer et al., 2019). The loss of coral reefs in remote islands of Boigu in Australia are 33 affecting low-lying communities facing financial, institutional (Evans et al., 2016) and cultural place-based 34 attachment adaptation limits (McNamara et al., 2017). Another hard limit to adaptation and implications for 35 income, and culture-and place-based livelihoods is related to the sensitivity of global fish to global 36 temperature increase with losses of fish reproduction expected to 10% (SSP1–1.9) to about 60% (SSP5–8.5) 37 potentially cascading into severe risks for fisheries livelihoods (Dahlke et al., 2020). In West African 38 fisheries, the loss of coastal ecosystems and productivity are estimated to require 5–10% of countries' gross 39 domestic product (GDP) in adaptation costs (Zougmoré et al., 2016), incurring financial limits in the poor 40 countries to avoid socio-economic risks. The SROCC (IPCC, 2019b) showed that scientific knowledge 41 limitations can constrain management of coastlines, mainly in the context of lack of data with affect most of 42 the vulnerable and poor communities in the global south (Perkins et al., 2015; Sutton-Grier et al., 2015; 43 Wigand et al., 2017; Romañach et al., 2018). The hard and soft adaptation limits are challenging to be 44 defined, given the rate and intensity of climate change hazards and the mitigation and adaptation options 45 available, but also the level and rate of non-climatic stresses increasing vulnerabilities and undermining 46 adaptive capacity of poorest members of society and sensitive ecosystems (medium evidence, high 47 agreement) (Klein et al., 2014; Roy et al., 2018). | Heritage | 1544 - 1544 |
| IPCC | IPCC_AR6_WGII_Full_Report | 1.5°C; Chapter 3, Box 3.5 (Hoegh-Guldberg et al., 2018); Chapter 4, Cross�chapter Box 4.1 (de Coninck et al., 2018)); The projected SLR is projected to affect human health and wellbeing, cultural and natural heritage, freshwater, biodiversity, agriculture, and fisheries (IPCC, 2018b; WHO, 2018; IDMC, 2019; McMichael et al., 2020). | Heritage | 1547 - 1547 |
| IPCC | IPCC_AR6_WGII_Full_Report | 1 2 3 8.4.5.7 Compounding future risks on equity and sustainability 4 5 The compounding future effects on equity and sustainability emerge when multiple stressors linked to 6 environmental and/or climate change, together with underlying structural poverty, exclusion, 7 marginalization, and conflicts creating risks that need to be addressed simultaneously. Compounding risks of 8 climate change received attention in AR5 (Oppenheimer et al., 2014) including risks associated with 9 compound hazards (O'Neill et al., 2017b), and their implications for future risk when repeated impacts erode 10 human and ecosystem capacity, including through transboundary effects. In SRCCL (IPCC, 2019a), land 11 degradation and climate change compounded to highly expose the livelihoods of the poor to climate hazards 12 and caused food insecurity (high confidence), migration, conflict and loss of cultural heritage (low 13 confidence) (Olsson et al., 2019). | Heritage | 1548 - 1548 |
| IPCC | IPCC_AR6_WGII_Full_Report | 25 26 Climate change affects people inequitably, and everyone does not contribute equally to climate change. A 27 range of economic and non-economic impacts can be experienced. This has led some researchers to call for a 28 more central role for rights-based approaches to adaptation, to help secure space for those marginalised from 29 adaptation decision making and to prioritise access to resources and information for those most vulnerable 30 to, or affected by, the social, cultural or economic consequences of climate change (Bee et al., 2013; Da 31 Costa, 2014; Toussaint and Martinez Blanco, 2020; Box 8.7; Section 5.12). In terms of international law, the 32 human rights obligations of states have been subject to multiple recommendations relating to climate change 33 by UN treaty bodies in the reporting period. More broadly, rights-based approaches rely on the normative 34 framework of human rights, requiring adaptation to be non-discriminatory, participatory, transparent and 35 accountable in both formal (e.g., legal and regulatory) and informal (e.g., social or cultural norms) settings 36 and at international, national and sub-national scales (Ensor et al., 2015; Arts, 2017). Sovacool et al. (2015) 37 note that unless critical competing interests are addressed during planning, adaptations may fail to achieve 38 the desired outcomes. This is increasingly seen at a political level within efforts to implement the Paris 39 Agreement, in relation to the principle of 'Common but Differentiated Responsibilities and Respective 40 Capacities' (CBDR-RC) (Box 8.7). | Heritage | 1552 - 1552 |

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| Organisation | Document | Quotation Content | Codes | Page |
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| IPCC | IPCC_AR6_WGII_Full_ Report | 52 53 There is broad support for the notion, enshrined in the Paris Agreement, that adaptation finance flowing to 54 developing countries of the Global South should primarily benefit the most climate-vulnerable among them 55 due to their limited technical capacity and financial capabilities, yet such countries are often insufficiently 56 considered in funding decisions. There are nevertheless concerns regarding institutional fit: that foreign 57 funding regimes may not map onto more recently developed administrative traditions, leading to dominance ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 8 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 8-81 Total pages: 155 1 of governance models emanating from donors (Vink and Schouten, 2018). Research has found multilateral 2 donors do not prioritise vulnerable developing countries at the project selection stage and they have received 3 smaller allocations of adaptation finance from bilateral donors than less vulnerable countries (Saunders, 4 2019), leaving the poor vulnerable to climate impacts. The lack of climate finance flowing to LDCs and 5 SIDs (currently 14 and two percent of the total, respectively) is compounded by access issues due to the 6 inability of domestic institutions to meet specific fiduciary standards and other access requirements, 7 insufficient human resource support and the inflexibility of current approaches which are biased in favour of 8 governments and against non-traditional actors such as local enterprise and grassroots organisations (Shakya 9 et al., 2021). Further, vulnerable developing countries shoulder additional financial burden, embodied in 10 higher interest payments to service public and private debt, due to the increased cost of capital brought about 11 by greater exposure to climate risks (Buhr et al., 2018). This has been further exacerbated by the recession 12 and debt distress accompanying the Covid-19 pandemic (Kose et al., 2021). A range of reforms, including 13 comprehensive debt relief by public creditors, green recovery bonds, debt-for-climate swaps and new SDG- 14 aligned debt instruments may address unsustainable debt burdens, freeing up investment in climate 15 adaptation and a green economic recovery (Volz et al., 2020; see Section 8.6.3.1).. | Heritage | 1555 - 1556 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 30 31 Policies and investments that are adopted are embedded within the relevant legal and regulatory frameworks, 32 which extend beyond national jurisdictions upward to the regional scale (such as the Southern Africa 33 Development Community's Southern Africa Regional Framework of Climate Change Programmes, (2010)) 34 and international scale, for example, UNFCCC, the 2015 Paris Agreement, the Sendai Framework for 35 Disaster Risk Reduction, the New Urban Agenda and the SDGs. Legal and regulatory concerns also extend 36 downward to shape local- and city-scale adaptation efforts (e.g., Sao Paulo's municipal policy and new 37 master plan). Nevertheless, only a minority of countries have dedicated legal frameworks supporting 38 adaptation (Lesnikowski et al., 2017) and these often lack in both precision and obligation—largely because 39 adaptation is a contested global public good but also because adaptation is commonly bundled in with 40 mitigation commitments (Hall and Persson, 2018). Coherence, horizontally and vertically in both policy and 41 law is often lacking. At the same time, bottom-up, private, autonomous adaptation efforts are being better 42 tracked, with different actors motivated by growing experiences of local climate change impacts (Berrang- 43 Ford et al., 2014).While the emergent polycentricity of adaptation governance is beginning to take shape, 44 wherein both state and non-state actors share a common adaptation goal and interact coherently, yet often 45 independently, to advance progress towards it (Morrison et al., 2019), understandings of how various centres 46 of decision making with different degrees of autonomy support an enabling environment for adaptation, 47 remain at a nascent stage . Multiple scales and forms of adaptation occur, with attributes such as self- 48 organisation, appreciation of site-specific conditions, and the need for learning and experimentation, 49 alongside building of trust, increasingly shown to be vital (Dorsch and Flachsland, 2017). Literature 50 indicates that professional and learning networks are important groups supporting adaptation in cities and 51 can help harness resources (Woodruff, 2018); while (Hauge et al., 2019) research in Norway underscores the 52 importance of working across multiple disciplines and the inclusion of actors from different levels of 53 authority in multilevel municipal networks. They found that these factors can help to identify specific 54 adaptation actions as well support knowledge sharing within participating organisations, which in turn helps 55 garner commitment to adaptation and its implementation. They also found that it is important to involve 56 local leaders in polycentric adaptation networks. | Heritage | 1556 - 1556 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 2 Indigenous Knowledge systems as they are embedded in culture, and are passed from generation to 3 generation in various ways: livelihoods, traditions, spiritual practices and oral tradition, cultural identity, and 4 historical memory. Indigenous Knowledge is known or learnt from experience, or acquired through 5 observation and practice, and handed down from generation to generation. It is acknowledged that 6 Indigenous Peoples communities, particularly those in hazard-prone areas, have developed a profound 7 understanding and knowledge of disaster prevention and mitigation, early warning, preparedness and 8 response, and post disaster recovery. While Indigenous Knowledge systems, themselves, are an 9 indispensable dimension of capacity for adaptation, and where threatened represent a major risk to 10 Indigenous Peoples communities. While still robust among Indigenous Peoples in many parts of Africa, Asia 11 and Latin America, Indigenous Knowledge is not well reflected or incorporated in assessments such as this, 12 and stands in danger of being lost as its custodians are passing away. | Heritage | 1560 - 1560 |

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| Organisation | Document | Quotation Content | Codes | Page |
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| IPCC | IPCC_AR6_WGII_Full_Report | 51 52 53 Table Box 8.8.1: Coping and adaptation actions enacted in the cyclone Aila affected area in response to losses of and 54 damage to physical capital Coping and adaptation actions Action group References ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 8 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 8-87 Total pages: 155 Human migration—mostly forced due to loss of houses as well as other resources and livelihood activities Households (Abdullah et al., 2016; Mallick et al., 2017; Paul and Chatterjee, 2019) Alternative livelihood activities such as crafts, and honey and wood collection from the Sundarbans, due to irreparable damage to fishing gear Households (Alam et al., 2015) Saving money for house repairs or construction Households (Alam et al., 2015) Underground storage of emergency items such as foods, matchbox, cooker and cooking fuel Households (Alam et al., 2015) Selection of high land to build shelter along both sides of the embankments Households (Alam et al., 2015) Tree plantation in the homestead periphery to protect the house from gusty winds and to use as a source of wood for house repair/construction Households (Alam et al., 2015) Increasing height of the house plinth Households (Alam et al., 2015) Changing of house roofing material from thatched to corrugated iron sheet or asbestos Households (Alam et al., 2015) Informally allowing people to harvest Sundarbans forest wood without any charge so they could make makeshift houses Forest Department (Abdullah et al., 2016) Rainwater harvesting using plastic or clay pots and artificial aquifer tube-wells for securing drinking water. | Heritage | 1561 - 1562 |
| IPCC | IPCC_AR6_WGII_Full_Report | 24 25 Similarly, technology must always be grounded in an appreciation of the cultural context. Research in the 26 European Arctic with the Indigenous Sami Peoples found that use of GPS technology on reindeer, together 27 with supplementary feeding, offer useful adaptations for some herders. However, there are fears such 28 technologies may, over time, reduce the skills, cultural knowledge and Indigenous adaptations of the Sami 29 (Andersson and Keskitalo, 2017), as, for example, reindeer become more tame through supplementary 30 feeding, affecting their range selection. Overall, technology and other adaptations should seek not to erode 31 Sami culture's adaptive capacity (Vuojala-Magga et al., 2011; Risvoll and Hovelsrud, 2016), particularly 32 because reindeer grazing as a land management practice can play a useful climate change mitigation role too. | Heritage | 1563 - 1563 |
| IPCC | IPCC_AR6_WGII_Full_Report | 22 Funds were raised from households through donations via a self-imposed sales tax. While this example 23 paints a positive picture of the role of social capital and collective action in adaptation activities, it also raises 24 questions about the coherence of actions across levels, again, highlighting a role for polycentric governance 25 if risks of maladaptation are to be reduced. The danger in the example presented here is that should federal 26 plans in future conflict with the community level work, local efforts may have been in vain if installations 27 have to be removed. This highlights the importance of careful evaluation of all adaptation options on an 28 ongoing basis. | Heritage | 1564 - 1564 |
| IPCC | IPCC_AR6_WGII_Full_Report | 39 40 Potential opportunities from CSA may also result from Integration of "technological packages" (Totin et al., 41 2018), which include new market structures; knowledge infrastructure and agriculture extension services; 42 and capacity building programs (Dougill et al., 2017; Totin et al., 2018); institutional support for key 43 enabling programs, such as crop insurance, agro-advisories and rainwater harvesting (Khatri-Chhetri et al., 44 2017). CSA is able—if carefully designed—to achieve transformative "triple wins" for climate and 45 development when it is accompanied by new governance architectures that are socially inclusive and 46 respectful of traditions and livelihoods, and accommodate traditional institutions that underpin the 47 bargaining power of the poorest and most vulnerable groups (Karlsson et al., 2017). | Heritage | 1570 - 1570 |
| IPCC | IPCC_AR6_WGII_Full_Report | 47 48 Policies supporting sustainable rangeland management and the livelihood strategies of rangeland users have 49 an outsized influence on both development and climate action (Gharibvand et al., 2015). Climate change 50 adaptation, mitigation practices and livestock production can be supported by policies that encourage 51 diversification of livestock animals (within species), support sustainable foraging and feed varieties (Rivera- 52 Ferre et al., 2016), strengthen institutions such as agricultural support programs, markets and intra- and inter- 53 regional trade (Zhang et al., 2017). For example, sustainable pastoralism can contribute to mitigation both by 54 increasing carbon sequestration through improved soil management and by reducing methane emissions 55 through changing the mix and distribution of the herd. Likewise sustainable pastoralism can also contribute 56 to adaptation by changing grazing management, introducing alternative livestock breeds, pest management, 57 and modified production structures (Joyce et al., 2013). Another example of rangeland adaptation is ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 8 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 8-97 Total pages: 155 1 diversifying the use of rangelands such as supplementing with payments for ecosystem services, carbon 2 sequestration, tourism or supplementary assistance for all land based activities (Gharibvand et al., 2015). | Heritage | 1571 - 1572 |

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| IPCC | IPCC_AR6_WGII_Full_Report | 12 13 This chapter builds from AR5 and 1.5°C Report on key limits to the adaptation of natural and social systems 14 since that are compounded by the effects of poverty and inequality such as on water scarcity, ecosystems 15 alteration and degradation, coastal cities in relation to sea-level rise, cyclones and coastal erosion, food 16 systems and human health (high confidence). The climate change risks substantially pose negative impacts 17 on climate-sensitive livelihoods of smallholder farmers, fisheries communities, Indigenous People, urban 18 poor, informal settlements, with limits to adaptation evidenced on the loss income, ecosystems, health, and 19 increasing migration (high confidence). It also addresses how ecological thresholds and socio-economic 20 determinants of vulnerabilities are linked to soft and hard adaptation limits, including the potential and 21 magnitude to livelihoods risks in the future. For instance, a hard limit associated to losses of coral reefs at 22 1.5°C warmer world will lead to substantial loss of income and livelihoods for coastal communities (high 23 confidence), including loss of culture and place-based attachment (medium confidence). The adaptation hard 24 limits are expected for the Arctic ecosystem, whose threshold will affect residents of Arctic regions 25 dependent on hunting and fishing livelihoods (high confidence). New emerging considerations to ecological 26 limits to adaptation such as severe glacier retreat and Amazon Forest dieback, is expected to affect the 27 livelihoods of smallholder's farmers, and Indigenous People through crops yield failures, biodiversity loss, 28 reduced hydropower capacity and heath (medium evidence). While a knowledge gap remains on the 29 projected risks of increasing global temperature to climate-sensitive livelihoods among global south 30 countries and specific groups of people, current observations show negative impacts to livelihoods for tens to 31 hundreds of millions of people. Thus, without sustainable, equitable and urgent adaptation measures, 32 maladaptation risks are likely to further increase vulnerability, marginalization, and ecological tipping points 33 among the poor within countries (medium confidence). | Heritage | 1581 - 1581 |
| IPCC | IPCC_AR6_WGII_Full_Report | 34 35 Evidence on the kinds of enabling environment required paints a complex picture. The assessment highlights 36 the interaction of different capital assets with the broader context of key enablers in shaping the overall 37 enabling environment for adaptation, which itself is highly context-dependent. In this regard, countries 38 present different starting points for adaptation, with some requiring, for example, more of an emphasis on 39 institutional capacity building; others requiring transformation to the broader legal and political conditions. | Heritage | 1581 - 1581 |
| IPCC | IPCC_AR6_WGII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 8 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 8-117 Total pages: 155 1 Bryant, L. and B. Garnham, 2015: The fallen hero: masculinity, shame and farmer suicide in Australia. Gender, Place 2 & Culture, 22(1), 67-82, doi:https://doi.org/10.1080/0966369X.2013.855628. | Heritage | 1591 - 1592 |
| IPCC | IPCC_AR6_WGII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 8 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 8-120 Total pages: 155 1 Crate, S. A., 2011: Climate and culture: anthropology in the era of contemporary climate change. Annual Review of 2 Anthropology, 40, 175-194, doi:10.1146/annurev.anthro.012809.104925. | Heritage | 1594 - 1595 |
| IPCC | IPCC_AR6_WGII_Full_Report | 7 {9.5.3–7, 9.7} 8 9 Glaciers on the Rwenzoris and Mt. Kenya are projected to disappear by 2030, and by 2040 on 10 Kilimanjaro (medium confidence). {9.5.8} 11 12 In East and southern Africa, tropical cyclones making landfall are projected to become less frequent 13 but have more intense rainfall and higher wind speeds at increasing global warming (medium 14 confidence). {9.5.7} 15 16 Heat waves on land, in lakes, and in the ocean will increase considerably in magnitude and duration 17 with increasing global warming (very high confidence). Under a 1.5°C-compatible scenario, children born 18 in Africa in 2020 are likely to be exposed to 4–8 times more heat waves compared to people born in 1960, 19 increasing to 5–10 times for 2.4°C global warming. The annual number of days above potentially lethal heat 20 thresholds reaches 50–150 in west Africa at 1.6°C global warming, 100–150 in Central Africa at 2.5°C, and 21 200–300 over tropical Africa for >4°C. {9.5.2, 9.5.3, 9.5.4, 9.5.5, 9.5.6, 9.7.2.1} 22 23 Most African countries will enter unprecedented high temperature climates earlier in this century 24 than generally wealthier, higher latitude countries, emphasising the urgency of adaptation measures in 25 Africa (high confidence). {9.5.1} 26 27 Compound risks 28 Multiple African countries are projected to face compounding risks from: reduced food production 29 across crops, livestock and fisheries; increasing heat-related mortality; heat-related loss of labour 30 productivity; and flooding from sea level rise, especially in West Africa (high confidence). {9.8.2, 9.8.5, 31 9.9.4, 9.10.2, 9.11.2} 32 33 Water 34 Recent extreme variability in rainfall and river discharge (c. -50% to +50% relative to long-term 35 historical means) across Africa have had largely negative and multi-sector impacts across water- 36 dependent sectors (high confidence) {9.7.2, 9.10.2}. Hydrological variability and water scarcity have 37 induced cascading impacts from water-supply provision and/or hydro-electric power production to health, 38 economies, tourism, food, disaster risk response capacity and increased inequality of water access. {Box 9.4} 39 40 Extreme hydrological variability is projected to progressively amplify under all climate scenarios 41 relative to the current baseline, depending on region (high confidence). Projections of numbers of people 42 exposed to water stress by the 2050s vary widely—decreases/increases by hundreds of millions, with higher 43 numbers for increases—with disagreement among global climate models the major factor driving these large 44 ranges. Populations in drylands are projected to more than double. Projected changes present heightened 45 cross-cutting risks to water-dependent sectors, and require planning under deep uncertainty for the wide 46 range of extremes expected in future. {9.7.1, 9.7.2} 47 48 Economy and Livelihoods 49 Climate change has reduced economic growth across Africa, increasing income inequality between 50 African countries and those in temperate, Northern Hemisphere climates (high confidence). One 51 estimate suggests GDP per capita for 1991–2010 in Africa was on average 13.6% lower compared to if 52 climate change had not occurred. Impacts manifest largely through losses in agriculture, as well as tourism, 53 manufacturing, and infrastructure. {9.6.3, 9.11.1} 54 55 Climate variability and change undermine educational attainment (high agreement, medium evidence). | Heritage | 1636 - 1636 |

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| IPCC | IPCC_AR6_WGII_Full_Report | 40 Increased rainfall variability is expected to affect electricity prices in countries highly dependent on 41 hydropower. {9.9.4; Boxes 9.4, 9.5} 42 43 Ecosystems 44 Increasing CO2 levels and climate change are destroying marine biodiversity, reducing lake 45 productivity, and changing animal and vegetation distributions (high confidence). Impacts include 46 repeated mass coral bleaching events in east Africa, and uphill (birds) or poleward (marine species) shifts in 47 geographic distributions. For vegetation, the overall observed trend is woody plant expansion, particularly 48 into grasslands and savannas, reducing grazing land and water supplies. {9.6.1} 49 50 The outcome of interacting drivers operating in opposing directions on future biome distributions is 51 highly uncertain. Further increasing CO2 concentrations could increase woody plant cover, but increasing 52 aridity could counteract this, destabilising forest and peatland carbon stores in central Africa (low 53 confidence). {9.6.2.1} 54 55 African biodiversity loss is projected to be widespread and escalating with every 0.5ºC increase above 56 present-day global warming (high confidence). Above 1.5°C, half of assessed species are projected to lose 57 over 30% of their population or area of suitable habitat. At 2°C, 36% of freshwater fish species are ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 9 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 9-9 Total pages: 225 1 vulnerable to local extinction, 7–18% of species assessed are at risk of extinction, and over 90% of East 2 African coral reefs could be destroyed by bleaching. Above 2°C, risk of sudden and severe biodiversity 3 losses becomes widespread in West, Central and East Africa. Climate change is also projected to change 4 patterns of invasive species spread. {9.6.2} 5 6 Climate security 7 There is increasing evidence linking increased temperatures and drought to conflict risk in Africa 8 (high confidence). Agriculturally dependent and politically excluded groups are especially vulnerable to 9 drought-associated conflict risk. However, climate is one of many interacting risk factors, and may explain a 10 small share of total variation in conflict incidence. Ameliorating ethnic tensions, strengthening political 11 institutions, and investing in economic diversification could mitigate future impacts of climate change on 12 conflict. {Box 9.9} 13 14 Heritage 15 African cultural heritage is already at risk from climate hazards, including sea level rise and coastal 16 erosion. Most African heritage sites are neither prepared for, nor adapted to, future climate change 17 (high confidence). {9.12} 18 19 Adaptation 20 21 With global warming increasing above present-day levels the ability of adaptation responses to offset 22 risk is substantially reduced (high confidence). Crop yield losses, even after adaptation, are projected to 23 rise rapidly above 2°C global warming. Limits to adaptation are already being reached in coral reef 24 ecosystems. Immigration of species from elsewhere may partly compensate for local extinctions and/or lead 25 to local biodiversity gains in some regions. However, more African regions face net losses than net gains. At 26 1.5°C global warming, over 46% of localities face net losses in terrestrial vertebrate species richness with net 27 increases projected for under 15% of localities. {9.6.1.4, 9.6.2.2, 9.8.2.1, 9.8.2.2, 9.8.4} 28 29 Technological, institutional, and financing factors are major barriers to climate adaptation feasibility 30 in Africa (high confidence). {9.3, 9.4.1} 31 32 There is limited evidence for economic growth alone reducing climate damages, but under scenarios of 33 inclusive and sustainable development, millions fewer people in Africa will be pushed into extreme 34 poverty by climate change and negative impacts to health and livelihoods can be reduced by 2030 35 (medium confidence). {9.10.3, 9.11.4} 36 37 Gender-sensitive and equity-based adaptation approaches reduce vulnerability for marginalised 38 groups across multiple sectors in Africa, including water, health, food systems and livelihoods (high 39 confidence). {9.7.3, 9.8.3, 9.9.5, 9.10.3, 9.11.4; Boxes 9.1, 9.2} 40 41 Integrating climate adaptation into social protection programs, such as cash transfers, public works 42 programmes and healthcare access, can increase resilience to climate change (high confidence). | Heritage | 1638 - 1639 |
| IPCC | IPCC_AR6_WGII_Full_Report | 43 Nevertheless, social protection programs may increase resilience to climate-related shocks, even if they do 44 not specifically address climate risks. {9.4.2, 9.10.3, 9.11.4} 45 46 The diversity of African indigenous knowledge and local knowledge systems provide a rich foundation 47 for adaptation actions at local scales (high confidence). African indigenous knowledge systems are 48 exceptionally rich in ecosystem-specific knowledge used for management of climate variability. Integration 49 of indigenous knowledge systems within legal frameworks, and promotion of indigenous land tenure rights 50 can reduce vulnerability. {9.4.4; Box 9.1, Box 9.2} 51 52 Early warning systems based on targeted climate services can be effective for disaster risk reduction, 53 social protection programmes, and managing risks to health and food systems (e.g., vector-borne 54 disease and crops) (high confidence). {9.4.5, 9.5.1, Box 9.2, 9.8.4, 9.8.5, 9.10.3, 9.11.4} 55 56 Risk-sensitive infrastructure delivery and equitable provision of basic services can reduce climate 57 risks and provide net financial savings (high confidence). However, there is limited evidence of pro-active ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 9 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 9-10 Total pages: 225 1 climate adaptation in African cities. Proactive adaptation policy could reduce road repair and maintenance 2 costs by 74% compared to a reactive policy. Adapting roads for increased temperatures and investment in 3 public transport are assessed as 'no regret' options. In contrast, hydropower development carries risk of 4 regrets due to damages when a different climate than was expected materializes. Energy costs for cooling 5 demands are projected to accumulate to USD 51.3 billion in 2035 at 2℃ global warming and to USD 486.5 6 billion in 2076 at 4℃. {9.8.5} 7 8 Reduced drought and flood risk, and improved water and sanitation access, can be delivered by: 9 water-sensitive and climate scenario planning, monitored groundwater use, waterless on-site 10 sanitation, rainwater harvesting and water reuse, reducing risk to human settlements, food systems, 11 economies, and human health (high confidence). {9.8, 9.9, 9.10, 9.11} 12 13 Water sector adaptation measures show medium social and economic feasibility but low feasibility for 14 most African cities due to technical and institutional restrictions, particularly for large supply dams 15 and centralised distribution systems (medium confidence). {9.3.1, 9.7.3} Use of integrated water 16 management, water supply augmentation, and establishment of decentralised water management systems can 17 reduce risk. Integrated water management measures including sub-national financing, demand management 18 through subsidies, rates and taxes, and sustainable water technologies can reduce water insecurity caused by 19 either drought or floods (medium confidence). {9.7.3; Box 9.4} 20 21 Agricultural and livelihood diversification, agroecological and conservation agriculture practices, 22 aquaculture, on-farm engineering, and agroforestry can increase resilience and sustainability of food 23 systems in Africa under climate change (medium confidence). However, smallholder farmers tend to 24 address short-term shocks or stresses by deploying coping responses rather than transformative adaptations. | Heritage | 1639 - 1640 |

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| IPCC | IPCC_AR6_WGII_Full_Report | 19 20 21 Table 9.1: Loss and damage from climate change across sectors covered in this report. Loss and damage arise from 22 adverse climate-related impacts and risks from both sudden-onset events, such as floods and cyclones, and slower-onset 23 processes, including droughts, sea level rise, glacial retreat and desertification and includes both include both economic 24 (e.g., loss of assets and crops) and non-economic types (e.g., loss of biodiversity, heritage and health) (UNFCCC Paris 25 Agreement, 2015; IPCC, 2018a; Mechler et al., 2020). Section marked with * and in bold highlights Loss and Damage 26 attributed to anthropogenic climate change (16.1.3). | Heritage | 1647 - 1647 |
| IPCC | IPCC_AR6_WGII_Full_Report | 10 11 Several key risks were identified for both ecosystems and people including species extinction and ecosystem 12 disruption, loss of food production, reduced economic output and increased poverty, increased disease and 13 loss of human life, increased water and energy insecurity, loss of natural and cultural heritage, and 14 compound extreme events harming human settlements and critical infrastructure (Table 9.2). In order to 15 provide a sector and continent-level perspective, the key risks aggregate across different regions and 16 combine multiple risks within sectors. For detailed assessments of observed impacts and future risks within 17 each sector and each sub-region of Africa, see the sector-specific sections of this chapter (Sections 9.6.1 and 18 9.12.1). | Heritage | 1648 - 1648 |
| IPCC | IPCC_AR6_WGII_Full_Report | 33 34 Glacial ice cover is projected to disappear before 2030 on the Rwenzori Mountains (Taylor et al., 2006) and 35 Mount Kenya (Prinz et al., 2018) and by 2040 on Kilimanjaro (Cullen et al., 2013). The loss of glaciers is 36 expected to result in a loss in tourism revenues, especially in mountain tourism (Wang and Zhou, 2019). | Heritage | 1687 - 1687 |
| IPCC | IPCC_AR6_WGII_Full_Report | (Fabiyi and Oloukoi, 2013; Hooli, 2016; Lunga and Musarurwa, 2016; Bwambale et al., 2018; Tume et al., 2019) Wildfires Early burning to prevent the intensity of the late-season fires Smallholders in Mutoko, Zimbabwe; Khwe and Mbukushu communities in Namibia (Mugambiwa, 2018; Humphrey et al., 2021) Rainfall variability Change crop type (from maize to traditional millet and sorghum); no weeding; forecasting, rainwater harvesting; women perform rituals rainmaking, seed dressing and crop maintenance as adaptation measures; mulching Communities in Accra, Ghana; small-scale farmers in Ngamiland in Botswana; Malawi; Zimbabwe; Women in Dikgale, South Africa, agropastoral smallholders in Ntungamo, Kamuli and Sembabule in Uganda. | Heritage | 1689 - 1689 |
| IPCC | IPCC_AR6_WGII_Full_Report | 15 16 Mangroves, seagrasses and coral reefs support nursery habitats for fish, sequester carbon, trap sediment and 17 provide shoreline protection (Ghermandi et al., 2019). Climate change is compromising these ecosystem 18 services (medium confidence). Marine heatwaves associated with El Niño-Southern Oscillation (ENSO) 19 events triggered massive coral bleaching and mortality over the past 20 years (Oliver et al., 2018). Mass 20 coral bleaching in the western Indian Ocean occurred in 1998, 2005, 2010 and 2015/2016 with coral cover 21 just 30–40% of 1998 levels by 2016 (Obura et al., 2017; Moustahfid et al., 2018). The northern Mozambique 22 Channel has served as a refuge from climate change and biological reservoir for the entire coastal East 23 African region (McClanahan et al., 2014; Hoegh-Guldberg et al., 2018). A southern shift of mangrove 24 species has been observed in South Africa (Peer et al., 2018) with loss in total suitable coastal habitats for 25 mangroves and shifts in the distribution of some species of mangroves and a gain for others (Record et al., 26 2013). Mangrove cover was reduced 48% in Mozambique in 2000 from tropical cyclone Eline, with 100% 27 mortality of seaward mangroves dominated by Rhizophora mucronata (Macamo et al., 2016). Recovery of 28 mangrove species was observed 14 years later in sheltered sites. There is low confidence these cyclone- 29 induced impacts are attributable to climate change owing, in part, to a lack of reliable long-term data sets 30 (Macamo et al., 2016). In West Africa, oil and gas extraction, deforestation, canalisation and de-silting of 31 waterways have been the largest factors in mangrove destruction (Numbere, 2019). | Heritage | 1694 - 1694 |
| IPCC | IPCC_AR6_WGII_Full_Report | 14 15 16 9.6.2.2 Terrestrial Biodiversity 17 18 Local extinction is when a species is extirpated from a local site. The magnitude and extent of local 19 extinctions predicted across Africa increase substantially under all future global warming levels (high 20 confidence) (Table 9.5; Figure 9.19). Above 2℃ the risk of sudden disruption or loss of local biodiversity, 21 increases and becomes more widespread, especially in Central, West and East Africa (Trisos et al., 2020). | Heritage | 1695 - 1695 |

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| IPCC | IPCC_AR6_WGII_Full_Report | Global Warming Level (relative to 1850-1900) Taxa % of species at a site at risk of local extinction Extent across Africa (% of the land area of Africa) Areas at risk References 1.5℃ Plants, insects, vertebrates >10% >90% Widespread. Hot and/or arid regions especially at risk, including Sahara, Sahel and Kalahari Fig. 9.29b (Newbold, 2018; Warren et al., 2018) >2℃ Plants, insects, vertebrates >50% 18% Widespread (Newbold, 2018; Warren et al., 2018) >4℃ Plants, insects, vertebrates >50% 45-73% Widespread. Higher uncertainty for central African tropical forests due to lower agreement between biodiversity models Fig. 9.29c (Barbet-Massin and Jetz, 2015; Newbold, 2018; Warren et al., 2018) 12 13 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 9 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 9-67 Total pages: 225 1 2 Figure 9.19: The loss of African biodiversity under future climate change is projected to be widespread and increasing 3 substantially with every 0.5℃ above the current (2001–2020) level of global warming (high confidence). (a) Projected 4 biodiversity loss, quantified as percentage change in species abundance, range size or area of suitable habitat increases 5 with increasing global warming levels (relative to 1850–1900). Above 1.5℃ global warming, half of all assessed 6 species are projected to lose >30% of their population, range size or area of suitable habitat, with losses increasing to 7 >40% for >3℃. The 2001–2020 level of global warming is around 1℃ higher than 1850–1900 (IPCC, 2021). Boxplots 8 show the median (horizontal line), 50% quantiles (box), and points are studies of individual species or of multiple 9 species (symbol size indicates the number of species in a study). (b–c) The mean projected local extinction of 10 vertebrates, plants and insects within 100 km grid cells increases in severity and extent under increased global warming 11 (relative to 1850–1900). Local extinction >10% is widespread by 1.5℃. Pixel colour shows the projected percentage of 12 species undergoing local extinction and the agreement between multiple biodiversity models. (d–e) The mean projected 13 increase in species of freshwater fish vulnerable to local extinction within 10 km grid cells for future global warming. | Heritage | 1696 - 1697 |
| IPCC | IPCC_AR6_WGII_Full_Report | 19 20 9.6.3 Nature-Based Tourism in Africa 21 22 Nature-based tourism is important for African economies and jobs. Tourism contributed 8.5% of Africa's 23 2018 GDP (World Travel and Tourism Council, 2019a) with Wildlife tourism contributing a third of tourism 24 revenue (USD 70.6 billion), supporting 8.8 million jobs (World Travel and Tourism Council, 2019b). | Heritage | 1699 - 1699 |
| IPCC | IPCC_AR6_WGII_Full_Report | 25 26 Climate change is already negatively affecting tourism in Africa (high confidence). The 2015–2018 Cape 27 Town drought caused severe water restrictions, reducing tourist arrivals and spending with associated job 28 losses (Dube et al., 2020). Anthropogenic climate change increased the likelihood of drought by a factor of 29 five to six (Pascale et al., 2020). Extreme heat days have increased across South African national parks since 30 the 1990s (van Wilgen et al., 2016). This reduces animal mobility, decreasing animal viewing opportunities 31 (Dube and Nhamo, 2020). Tourists and employees also fear heat stress (Dube and Nhamo, 2020). Visitors to 32 South Africa's national parks preferred to visit in cool-to-mild temperatures (Coldrey and Turpie, 2020). | Heritage | 1699 - 1699 |
| IPCC | IPCC_AR6_WGII_Full_Report | 33 Extreme weather conditions disrupted tourist activities and damaged infrastructure at Victoria Falls, Hwange 34 National Park, Kruger National Park and the Okavango Delta (Dube et al., 2018; Dube and Nhamo, 2018; 35 Mushawemhuka et al., 2018; Dube and Nhamo, 2020). Rainfall variability and drought alters wildlife 36 migrations, affecting tourist visits to the Serengeti (Kilungu et al., 2017). Reduced tourism decreases revenue 37 for national park management (van Wilgen et al., 2016). | Heritage | 1699 - 1699 |
| IPCC | IPCC_AR6_WGII_Full_Report | 38 39 Future climate change is projected to further negatively affect nature-based tourism. Decreased snow and 40 forest cover may reduce visits to Kilimanjaro National Park (Kilungu et al., 2019). Woody plant expansion 41 in savanna and grasslands reduce tourist's game viewing experience and negatively impact conservation 42 revenues (Gray Emma and Bond William, 2013; Arbieu et al., 2017). Visitation rates to South African 43 national parks, based on mean monthly temperatures, are projected to decline 4% with 2℃ global warming 44 (Coldrey and Turpie, 2020). Sea level rise and increased intensity of storms is projected to reduce beach 45 tourism due to beach erosion (Grant, 2015; Amusan and Olutola, 2017). Tourism in the Victoria Falls, 46 Okavango and Chobe hydrological systems may be negatively affected by heat and increased variability of 47 rainfall and river flow (Saarinen et al., 2012; Dube and Nhamo, 2019). Increased extreme heat will increase 48 air turbulence and weight restrictions on aircraft, which could make air travel more uncomfortable and 49 expensive to African destinations (Coffel and Horton, 2015; Dube and Nhamo, 2019). | Heritage | 1699 - 1699 |
| IPCC | IPCC_AR6_WGII_Full_Report | 50 51 9.6.3.1 Protected Areas and Climate Change 52 53 African protected areas store around 1.5% of global land ecosystem carbon stocks and support biodiversity 54 (Gray et al., 2016; Melillo et al., 2016; Sala et al., 2018). They also support livelihoods and economies, such 55 as through nature-based tourism and improved fisheries (Brockington and Wilkie, 2015; Mavah et al., 2018; 56 Ban et al., 2019). | Heritage | 1699 - 1699 |

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| IPCC | IPCC_AR6_WGII_Full_Report | 35 36 Yet many areas targeted by AFR100 erroneously mark Africa's open ecosystems (grasslands, savannas, 37 shrublands) as degraded and suitable for afforestation (Figure Box 9.3.1) (Veldman et al., 2015; Bond et al., 38 2019) (high confidence). These ecosystems are not degraded, they are ancient ecosystems that evolved in the 39 presence of disturbances (fire/herbivory) (Maurin et al., 2014; Bond and Zaloumis, 2016; Charles- 40 Dominique et al., 2016). Afforestation prioritises carbon sequestration at the cost of biodiversity and other 41 ecosystem services (Veldman et al., 2015; Bond et al., 2019). Furthermore, it remains uncertain how much 42 carbon can be sequestered as, compared to grassy ecosystems, afforestation can reduce belowground carbon 43 stores and increase aboveground carbon loss to fire and drought (Yang et al., 2019; Wigley et al., 2020b; 44 Nuñez et al., 2021). Thus, afforested areas may store less carbon than ecosystems they replace (Dass et al., 45 2018; Heilmayr et al., 2020). Afforestation would reduce livestock forage, eco-tourism potential and water 46 availability (Gray Emma and Bond William, 2013; Anadón et al., 2014; Cao et al., 2016; Stafford et al., 47 2017; Du et al., 2021), and may reduce albedo thereby increasing warming (Baldocchi and Penuelas, 2019; 48 Bright et al., 2015). | Heritage | 1702 - 1702 |
| IPCC | IPCC_AR6_WGII_Full_Report | 41 42 A substantial media campaign was launched to inform residents about the severity of the drought and urge 43 water conservation (Booysen et al., 2019; Hellberg, 2019; Ouweneel et al., 2020). Together with stringent 44 demand management through higher water tariffs, this communication campaign played an important role in 45 reducing consumption from 540 to 280 litres per household per day (Booysen et al., 2019; Simpson et al., 46 2019a). Revenue from water sales contributes 14% of Cape Town's total revenue, making it the third-largest 47 source of 'own' revenue for the city (Simpson et al., 2019b). However, with an unprecedented reduction in 48 water use, the municipal budget was undermined (Simpson et al., 2020b). Collecting less revenue created a 49 financial shock as the city struggled to recover operating finance, even while new capital requirements were 50 needed for the development of expensive new water supply projects (Simpson et al., 2019b). This financial 51 shock was compounded by the economic stress of poor agricultural and tourism performance brought about 52 by the drought (Shepherd, 2019; Simpson et al., 2021b). As wealthy residents invested in private, off-grid 53 water supplies, the risk of reduced municipal revenue collections from newly off-grid households aggregated 54 with the risk of reduced tourism, increasing the risk to the reputation of the incumbent administration 55 (Simpson et al., 2021b). This demonstrates how a population cohort with a high response capability to water 56 scarcity can reduce risk while simultaneously increasing risks to the municipality and its capacity to provide 57 water to vulnerable residents (Simpson et al., 2020b). Given that city populations in Africa pay 5–7 times ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 9 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 9-76 Total pages: 225 1 more for water than the average price paid in the United States or Europe (Adamu and Ndi, 2017; Lwasa et 2 al., 2018), municipal finance needs to delink operating revenue from potential climate shocks (see Box 8.6 in 3 Chapter 8). | Heritage | 1705 - 1706 |
| IPCC | IPCC_AR6_WGII_Full_Report | 45 46 In southern Africa, reductions in rainfall over the Limpopo and Zambezi river basins under 1.5℃ and 2℃ 47 global warming could have adverse impacts on hydropower generation, irrigation, tourism, agriculture and 48 ecosystems (Figure Box 9.5.1) (Maúre et al., 2018), although model projections of strong early summer 49 drying trends remain uncertain (Munday and Washington, 2019). | Heritage | 1707 - 1707 |
| IPCC | IPCC_AR6_WGII_Full_Report | 11 These studies often represent changes at specific sites in a country or assess changes in the yield and/or 12 suitability for cultivating a specific crop across a larger geographic area. Climate change is projected to have 13 overall positive impacts on sugarcane and Bambara nuts in southern Africa, oil palm in Nigeria and chickpea 14 in Ethiopia (low confidence) (Figure 9.23). | Heritage | 1717 - 1717 |
| IPCC | IPCC_AR6_WGII_Full_Report | 26 27 For all other crops, there is at least one study that finds low to highly negative impacts for one or several 28 warming levels (Figure 9.23). Mixed results on the direction of change often occur when several contrasting 29 sites with varying baseline climates are studied, and when a study considers the full range of climate 30 scenarios. For example, there are mixed results on the direction of change for impacts of 1.5℃ global 31 warming on cassava, cotton, cocoa and millet in West Africa (low confidence) (Figure 9.23). In general, 32 there is limited evidence in the direction of change, due to single studies being available for most crop- 33 country combinations (Knox et al., 2010; Chemura et al., 2013; Asaminew et al., 2017; Bouregaa, 2019). | Heritage | 1717 - 1717 |
| IPCC | IPCC_AR6_WGII_Full_Report | 26 27 Although warming temperatures are largely responsible for increasing environmental suitability for mosquito 28 vectors (Mordecai et al., 2019), droughts can augment transmission when open water storage provides 29 breeding sites near human settlements, and when flooding enables mosquitoes to proliferate and spread 30 viruses further (Mweya et al., 2017; Bashir and Hassan, 2019). Within Africa's rapidly growing cities, 31 diseases vectored by urban-adapted Aedes mosquitoes pose a major threat, especially in West Africa 32 (Zahouli et al., 2017; Weetman et al., 2018; Messina et al., 2019). Dengue virus expansion may cause 33 explosive outbreaks but the burden of dengue haemorrhagic fever and associated mortality is higher in areas 34 where transmission is already endemic (Murray et al., 2013). | Heritage | 1745 - 1745 |
| IPCC | IPCC_AR6_WGII_Full_Report | 10 Adaptation options can build on a long tradition of community-based services in Africa (Ebi and Otmani Del 11 Barrio, 2017). Indeed, strengthening many of the services already provided (e.g., childhood vaccinations and 12 vector control) will help curtail emerging burdens of climate-sensitive conditions. However, a 13 disproportionate focus on emerging zoonotic and vector-borne viruses could undermine climate change 14 adaptation efforts in Africa if it shifts the focus away from health system strengthening and leaves few 15 resources for addressing other health impacts of climate change. | Heritage | 1755 - 1755 |

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| IPCC | IPCC_AR6_WGII_Full_Report | 19 20 Improved water, sanitation and hygiene (WASH) requires robust water and sanitation infrastructure 21 (Duncker, 2017; Kohlitz et al., 2017; Venema and Temmer, 2017) and technological adaptations (Gabert, 22 2016; van Wyk et al., 2017), such as waterless on-site sanitation (Sutherland et al., 2021), diversification of 23 water sources (e.g., rainwater harvesting (Lasage and Verburg, 2015) and groundwater abstraction 24 (MacDonald et al., 2012)), and sharing of best practices across the continent (WASH Alliance International, 25 2015; Jack et al., 2016) (see also Section 9.7.3; Chapter 4, Section 4.6.4). Hand hygiene can be improved 26 through the creation of handwashing stations, increased access to soap and simple technologies such as the 27 foot-operated Tippy taps (Coultas and Iyer, 2020; Mbakaya et al., 2020). | Heritage | 1757 - 1757 |
| IPCC | IPCC_AR6_WGII_Full_Report | 32 Health promotion initiatives include promoting adequate hydration and simple cooling measures such as 33 drinking cold liquids, water sprays and raising awareness of the symptoms and importance of heat stress, 34 including heatstroke (Aljawabra and Nikolopoulou, 2018). Adaptive measures are especially important for 35 high-risk groups such as outdoor workers, the elderly, pregnant women and infants. Health systems 36 interventions may include early warning systems, heat health regulation, and health workers providing 37 cooling interventions, such as supplying cool water or fans, during heat waves. Changes to the built 38 environment include painting the roofs of houses white and improving ventilation during extreme heat 39 (Codjoe et al., 2020), the use of insulation materials or altering the building materials used for the 40 construction of housing to improve their ability to moderate indoor temperatures (Mathews et al., 1995; 41 Makaka and Meyer, 2006). | Heritage | 1757 - 1757 |
| IPCC | IPCC_AR6_WGII_Full_Report | Response category Co-benefits Inter-sectoral trade�offs and/or drawbacks Enablers Barriers Policy development Policies and plans that facilitate service delivery and guide national and international funding; decreased number of work hours lost; improved work performance, increased productivity Willingness of policymakers; political support; politically willing environment; inter-sectoral collaboration Lack of implementation; poor governance Education & awareness Promotion of sustainable living and circular economy Guarantee to sustained funding; political support; politically willing environment; increased accessibility of learning institutions Lack of implementation; historical and colonisation-related insensitivities Health systems & primary healthcare services Capacity building in communities; buffered economic impact of outbreaks/ disasters; job creation Increased GHG from building; increased energy demand; decreased productivity and increased work hours lost due to waiting times Guarantee to sustained funding; political support; politically willing environment Corruption and fraudulent activities around resource allocation Surveillance, risk assessments, monitoring, & research Evidence to improve adaptation response; fast post-disaster recovery; increased awareness and disease prevention; improved health system functioning post-disasters Requires effective institutional arrangements and inter�sectoral collaboration; guarantee to sustained funding; requires skills development May be limited by uncertainty in modelled predictions and thresholds Resource management Improved health system functioning post-disasters; capacity building in communities; promotes economic growth/stability; increases the tourism potential of the area; increased accessibility/ mobility of the community; reduced land degradation, desertification, and bush encroachment; food security; decreased emissions Increased GHG from building; increased energy demand; increased crowding/ population density; land use; microclimate and ecosystem disruption Guarantee to sustained funding; political support; politically willing environment; requires effective institutional arrangements and inter�sectoral collaboration; requires skills development Corruption and fraudulent activities around resource allocation Vector control & disease prevention Decreased mortality; improved work performance; increased productivity; improved mental health Increased GHG; decreased biodiversity; environmental impacts of production, packaging, and delivery; potentially detrimental to health Guarantee to sustained funding; funding and resources; future planning or retrofit required Last-mile access; cost per capita and capacity for service delivery 5 6 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 9 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 9-130 Total pages: 225 1 9.11 Economy, Poverty and Livelihoods 2 3 9.11.1 Observed Impacts of Climate Change on African Economies and Livelihoods 4 5 9.11.1.1 Economic Output and Growth 6 7 Increased average temperatures and lower rainfall have reduced economic output and growth in Africa, with 8 larger negative impacts than other regions of the world (Abidoye and Odusola, 2015; Burke et al., 2015a; 9 Acevedo et al., 2017; Kalkuhl and Wenz, 2020). In one estimate, GDP per capita is on average 13.6% lower 10 for African countries than it would be if anthropogenic warming since 1991 had not occurred (Diffenbaugh 11 and Burke, 2019), although impacts vary substantially across countries (see Figure 9.37). As such, global 12 warming has increased economic inequality between temperate, Northern Hemisphere countries and those in 13 Africa (Diffenbaugh and Burke, 2019). Warming also leads to differential economic damages within Africa 14 (Baarsch et al., 2020). One estimate found a 1℃ increase in 20-year average temperature reduced GDP 15 growth by 0.67 percentage points, with the greatest impacts in Central African Republic, Democratic 16 Republic of Congo and Zimbabwe (Abidoye and Odusola, 2015). Changes in rainfall patterns also influence 17 individual and national incomes. Had total rainfall not declined between 1960 and 2000, the gap between 18 African GDP and that of the rest of the developing world would be 15–40% smaller than today, with the 19 largest impacts in countries heavily dependent on agriculture and hydropower (Barrios et al., 2010). | Heritage | 1759 - 1760 |

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| Organisation | Document | Quotation Content | Codes | Page |
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| IPCC | IPCC_AR6_WGII_Full_ Report | 20 21 Aggregate macroeconomic impacts manifest through many channels (Carleton et al., 2016). Macroeconomic 22 evidence suggests aggregate impacts occurred largely through losses in agriculture with a smaller role for 23 manufacturing (Barrios et al., 2010; Burke et al., 2015b; Acevedo et al., 2017). Sector-specific analyses 24 confirm that declines in productivity of food crops, commodity crops and overall land productivity 25 contribute to lower macroeconomic performance under rising temperatures (Schlenker and Lobell, 2010; 26 Bezabih et al., 2011; Jaramillo et al., 2011; Lobell et al., 2011; Adhikari et al., 2015). Labour supply and 27 productivity declines in manufacturing, industry, services and daily wage labour have been observed in other 28 regions (Graff Zivin and Neidell, 2014; Somanathan et al., 2015; Day et al., 2019; Nath, 2020) and 29 contribute to aggregate economic declines, countering aggregate poverty reduction strategies and other 30 sustainable development goals (Satterthwaite and Bartlett, 2017; Day et al., 2019). In a case study of a rural 31 town in South Africa, over 80% of businesses (both formal and informal) lost over 50% of employees and 32 revenue due to agricultural drought (Hlalele et al., 2016). Drought and extreme heat events have also reduced 33 tourism revenues in Africa (Section 9.6.3). Infrastructure damage and transport disruptions from adverse 34 climate events reduce access to services and growth opportunities (Chinowsky et al., 2014). In global 35 datasets including Africa, tropical cyclones have been shown to have large and long-lasting negative impacts 36 on GDP growth (Hsiang and Jina, 2014). | Heritage | 1760 - 1760 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 5 While these reallocation effects may be large, current evidence is mixed regarding whether such adjustment 6 of production will dampen or amplify overall social costs of climate change in Africa (Costinot et al., 2012; 7 Bren d'Amour et al., 2016; Wenz and Levermann, 2016; Nath, 2020), as food prices are projected to rise by 8 2080-2099 across all African countries under a scenario with high challenges to mitigation and adaptation 9 (SSP3 and RCP8.5), with the largest price effects (up to 120%) experienced in Niger, Chad and Sudan (Nath, 10 2020). Moreover, reallocating production of agriculture abroad could be maladaptive if it leads to decline or 11 replacement of traditional sectors by industrial and service sectors which could lead to land abandonment, 12 food insecurity and loss of traditional practices and cultural heritage (Thorn et al., 2020; Gebre and Rahut, 13 2021; Nyiwul, 2021). | Heritage | 1764 - 1764 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 29 30 [END BOX 9.9 HERE] 31 32 33 9.12 Heritage 34 35 Africa is a rich reservoir of heritage resources and indigenous knowledge, showcased by about 96 sites 36 inscribed by UNESCO as World Heritage Sites (UNESCO, 2018b). These include 53 sites specifically 37 denoted as having great cultural importance and 5 sites with mixed heritage values. Unfortunately, valuable 38 cultural heritage in forms of tangible evidence of past human endeavour, and the intangible heritage 39 encapsulated by diverse cultural practices of many communities (Feary et al., 2016), is under great threat 40 from climate change. | Heritage | 1772 - 1772 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 43 44 For more than 10,000 years, Africans recorded over 8,000 painted and engraved images on rock shelters and 45 rock outcroppings across 800 exceptional rock art sites of incalculable value (Hall et al., 2007; di Lernia and 46 Gallinaro, 2011; di Lernia, 2017; Clarke and Brooks, 2018; Barnett, 2019), but which are exceptionally 47 fragile to the elements. Unfortunately, there has been a poor study of direct climate change impacts on rock 48 art across Africa. | Heritage | 1772 - 1772 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 49 50 Underwater heritage includes shipwrecks and artefacts lost at sea and extends to prehistoric sites, sunken 51 towns and ancient ports that are now submerged due to climatic or geological changes (Spalding, 2011). Off 52 the shores of Africa, about 111 shipwrecks have been documented, with South Africa having a major share 53 of about 41 sites. The sunken Egyptian city of Thonis-Heracleion and its associated 60+ shipwrecks reflect 54 the richness of Africa's waters. Unfortunately, increased storm surges and violent weather currently threaten 55 the integrity of shipwrecks by accelerating the destruction of wooden parts and other features (Harkin et al., 56 2020). However, climate change impacts on underwater cultural heritage sites are poorly studied, as it ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 9 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 9-143 Total pages: 225 1 requires specialist assessment techniques (Feary et al., 2016), and marine archaeology studies are not well- 2 established in Africa. | Heritage | 1772 - 1773 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 3 4 Intangible heritage includes instruments, objects, artefacts and cultural spaces associated with communities, 5 and are almost always held orally (UNESCO, 2003). Loss of heritage assets may be a direct consequence of 6 climate change/variability (Markham et al., 2016), or a consequence of indirect factors resulting from 7 climate change, for example, economic instability and poor decision-making in areas of governance. In 8 northern Nigeria, climate change exacerbates the impact of poor land use decisions, reducing the flow of the 9 Yobe River and negatively impacting the Bade fishing festival because the available fish species continue to 10 decline (Oruonye, 2010). Similarly, Lake Sanké in Mali has been degraded by a combination of urban 11 development and poor rainfall, threatening the Sanké mon collective fishing rite (UNESCO, 2018b). | Heritage | 1773 - 1773 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 17 18 Case study: Traditional earthen 'green energy' buildings 19 Historically, Africa has had a unique and sustainable architecture (Diop, 2018) characterised by area- 20 specific, traditional earthen materials and associated indigenous technology. Key examples include Tiébélé 21 in Burkina Faso, Walata in Mauritania, Akan in Ghana, Ghadames in Libya, Old Towns of Djenné in Mali 22 (World Heritage Site) and other diverse earthen architecture across sub-Saharan Africa. Adegun and Adedeji 23 (2017) indicate that earthen materials provide advantages in thermal conductivity, resistivity and diffusivity, 24 indoor and outdoor temperature, as well as cooling and heating capacities. Moreover, earthen materials are 25 recyclable and environmentally 'cleaner' (Sanya, 2012) because of the absence or small quantity of cement 26 in production, thus reducing carbon emissions. Despite these advantages, the expertise and socio-cultural 27 ceremonies that accompany building and renewal of earthen architecture are disappearing fast (Adegun and 28 Adedeji, 2017). Further, earthen construction is being threatened by extreme climatic variability and 29 changing climate that exacerbates decay (Brimblecombe et al., 2011; Bosman and Van der Westhuizen, 30 2014; Brooks et al., 2020). | Heritage | 1773 - 1773 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 31 32 9.12.2 Projected Risks 33 34 Sea level rise and its associated hazards will present increasing climate risk to African heritage in the coming 35 decades (Marzeion and Levermann, 2014; Reimann et al., 2018; Brito and Naia, 2020) (Figure 9.38). | Heritage | 1773 - 1773 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 36 Although no continental assessment has quantified climate risk to African heritage and little is known of near 37 term exposure to hazards such as sea level rise and erosion, for a handful of coastal heritage sites included in 38 global or Mediterranean studies, 10 cultural sites are identified to be physically exposed to sea level rise by 39 2100 at high emissions scenarios (RCP8.5) (Marzeion and Levermann, 2014; Reimann et al., 2018), of 40 which, 7 World Heritage Sites in the Mediterranean are also projected to face medium or high risk of erosion 41 (Reimann et al., 2018) (Figure 9.38). Further, Brito and Naia (2020) identify natural heritage sites across 27 42 African countries that will be affected by sea level rise by 2100 (RCP8.5), of which 15 sites covering eight 43 countries demonstrated a high need for proactive management actions because of high levels of biodiversity, 44 international conservation relevance and exposure to sea level rise (Figure 9.38). These nascent studies 45 highlight the potential severity of risk and loss and damage from climate change to African heritage, as well 46 as gaps in knowledge of climate risk to African cultural and natural, particularly concerning bio-cultural 47 heritage. | Heritage | 1773 - 1773 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 48 49 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 9 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 9-144 Total pages: 225 1 2 Figure 9.38: Risk to Africa's cultural and natural coastal heritage sites from sea level rise and erosion by 2100 3 (RCP8.5). Panel (a) Exposed World Heritage sites projected to be affected by sea level rise under a high-end sea level 4 rise scenario (RCP8.5, 2100) (Marzeion and Levermann, 2014; Reimann et al., 2018). Panel a call out) Sites identified 5 to be also exposed to medium and high erosion risk under current and future conditions (2000 and 2100) under a high- 6 end sea level rise scenario (Reimann et al., 2018). Panel (b) The 15 topmost African natural sites (coastal protected 7 areas) identified to be exposed to negative impacts from sea level rise and as priority for conservation (Brito and Naia, 8 2020). | Heritage | 1773 - 1774 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 9 10 11 Although climate change is a significant risk to heritage sites (Brito and Naia, 2020), there is little research 12 on how heritage management is adapting to climate change, and particularly, whether the capacity of current 13 heritage management systems can prepare for and deal with consequences of climate change (Phillips, 2015) 14 (see also Cross-Chapter Box SLR in Chapter 3). | Heritage | 1774 - 1774 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 15 16 Worsening climate impacts are cumulative and often exacerbate the vulnerability of cultural heritage sites to 17 other existing risks, including conflict, terrorism, poverty, invasive species, competition for natural resources 18 and pollution (Markham et al., 2016). These issues may affect a broad range of tourism segments, including 19 beach vacation sites, safari tourism, cultural tourism and visits to historic cities (UNWTO, 2008). Climate 20 change impacts have the potential to increase tourist safety concerns, especially at sites where increased 21 intensity of extreme weather events or vulnerability to floods and landslides are projected (Markham et al., 22 2016) (see also Cross-Chapter Box EXTREMES in Chapter 2). There may also be circumstances where 23 interventions required to preserve and protect the resource alter its cultural significance (van Wyk, 2017). | Heritage | 1774 - 1774 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 24 25 9.12.3 Adaptation 26 27 Research highlights potential in integrating indigenous knowledge, land use practices, scientific knowledge 28 and heritage values to co-produce tools that refine our understanding of climate change and variability and 29 develop comprehensive heritage adaptation policy (Ekblom et al., 2019) (Table 9.13). | Heritage | 1774 - 1774 |
| IPCC | IPCC_AR6_WGII_Full_ Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 9 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 9-145 Total pages: 225 1 Table 9.13: Examples of responses to climate change impacts to heritage sites. | Heritage | 1774 - 1775 |
| IPCC | IPCC_AR6_WGII_Full_ Report | Heritage Type Example Type of Climate Impact Intervention Focus or Activity Main Intervention Activity State of Materials Final State of Heritage Literature Tangible Ancient Historic buildings Ounga Byzantine Fort and associated archaeological remains, Tunisia Coastal erosion Archaeological conservation of fort Building repairs to outer walls of fort but other archaeological areas no intervention Mixed. Fort is in good condition, but other parts of the site are under threat of coastal erosion, particularly lesser archaeological remains of other periods Some aspects of site well preserved, other parts damaged (Slim et al., 2004) Archaeolo gical sites Sabratha, Roman City, Libyan coast Sea level rise, local flooding and coastal erosion Monitoring of condition None Loss of archaeological remains into the sea Some aspects of site well preserved, other parts damaged (Abdalahh, 2011) Living Cities / towns Lamu Old Town and archipelago, Kenya Sea Level Rise impacting low lying areas and climate variability impacting protective mangroves Lamu Old Town managed by National Museums of Kenya the mangrove forests by Community Forest Associations and Forest Conservation and Management Act of 2016. Changes in biodiversity and cultural resilience to climate shocks. | Heritage | 1775 - 1775 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | Current and ongoing conservation Stable (Birabi and Nawangwe, 2011) Bio�cultural Rock art Golden Gate Highlands, South Africa Precipitation and atmospheric changes Monitoring of condition No known intervention Biodeterioration of condition of rock surface Increasing loss of rock surfaces (Viles and Cutler, 2012) ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 9 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 9-146 Total pages: 225 causing luxuriant lichen growth and images on the rock surfaces Intangible (indigenou s) Language !Xun and Khwe Indigenous Youth of South Africa Climate variability causing drought and loss of plants Groups (youth) Documentation Non-formal, local Enhancem ent, promotion (Bodunrin, 2019) Indigenous Language Use in Agricultural Radio Programming in Nigeria Climate variability increasing frequency of drought Farmer groups, communities Research, documentation Formal, local Promotion, transmissio n (Adeyeye et al., 2020) Rituals Enkipaata, Eunoto and Olng'esherr Maasai male rites of passage Climate variability causing drought Maasai community groups Identification, documentation, research Formal, non-formal, local, foreign promotion (UNESCO, 2018a) Customs & beliefs Sanké mon fishing festival in Mali Climate variability reducing rainfall Malinkés, Bambara and Buwa communities Identification, documentation, preservation Formal, non-formal, local promotion (UNESCO, 2009) Indigenou s engineerin g systems Water measurers of the Foggara irrigation system in Algeria Increased siltation and sandstorms Climate variability causing flooding Touat and Tidikelt communities Research, identification, documentation Formal, local transmissio n (Mokadem et al., 2018) Arts and crafts Traditional crafts made from various parts of the Date Palm in Egypt, Mauritania, Morocco, Sudan, Tunisia and other countries outside Africa Climate variability causing shift in plant habitats Residents of oases, groups, communities, agricultural cooperative societies Research, identification, documentation, preservation, protection Formal, non-formal, local, foreign Transmissi on, promotion, enhanceme nt, revitalizati on (UNESCO, 2003) (Shabani et al., 2012) 1 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 9 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 9-147 Total pages: 225 1 Conservation of heritage may require offsetting the impact of loss through partial or total excavation under 2 certain circumstances, like environment instability, or where in situ heritage preservation is exorbitant in cost 3 (Maarleveld and Guérin, 2013). | Heritage | 1775 - 1777 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 4 5 Although many underwater shipwrecks and ruins of cities are currently preserved better in situ than similar 6 sites on land (Feary et al., 2016), preserving such heritage is often financially prohibitive with many physical 7 and technical challenges. Further, skill capacities of heritage agencies are limited to a few qualified 8 archaeologists in Africa (Maarleveld and Guérin, 2013). | Heritage | 1777 - 1777 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 9 10 For centuries, Africans have drawn on intangible heritage to enhance their resilience to climatic variability 11 and support adaptation practices. For example, pastoralist communities have historically translated their 12 experiences into memories that can be 'translated' into diverse adaptive practices (Oba, 2014). In coastal 13 Kenya, Mijikenda communities rely on indigenous knowledge and practices used in the management of the 14 sacred Kaya Forests to adapt their farming to a changing climate (Wekesa et al., 2015). | Heritage | 1777 - 1777 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 15 16 Hence, preservation measures for transforming oral information into written records should ensure viability 17 of intangible cultural heritage by giving due consideration to the confidentiality of culturally sensitive 18 information and intellectual property rights (Feary et al., 2016). | Heritage | 1777 - 1777 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 19 20 Inclusion of cultural landscapes and intangible heritage in the landscape approach at the regional scale 21 development planning processes may have significant impacts on protected area management (Feary et al., 22 2016). For example, at the Domboshava rock art site in Zimbabwe, all management decisions are taken in 23 direct consultation with traditional leaders and other stakeholders from surrounding communities (Chirikure 24 et al., 2010). Such adaptation strategies promote a more open-minded approach to heritage by leveraging 25 local development (UNESCO, 2018b). | Heritage | 1777 - 1777 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 26 27 Lack of expertise and resources, together with legislation that privileges certain typologies of heritage, seem 28 to limit implementation of approved policies (Ndoro, 2015). Additionally, cultural heritage has least priority 29 in terms of budgetary allocation, capacity building and inclusion into school curricula. Failure to consider the 30 views of people who attach spiritual significance to places is detrimental to the conservation of heritage 31 places (Bwasiri, 2011). In particular, documented cases of local people having to pay an entrance fee, like 32 tourists, to access burial grounds and places of pilgrimage negate local participation in cultural site 33 management (Ndoro, 2015). | Heritage | 1777 - 1777 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 34 35 In the long term, heritage managers and local authorities could shift from planning primarily for disaster 36 response and recovery to strategies that focus on disaster preparedness, reducing the vulnerability of sites 37 and strengthening resilience of local communities (UNFCCC, 2007; Domke and Pretzsch, 2016). This could 38 evolve into innovative approaches that integrate community, government and the research sector in 39 productive cultural heritage management partnerships. | Heritage | 1777 - 1777 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 40 41 There is a need for institutions to establish, maintain and update a comprehensive inventory of underwater 42 cultural heritage. This can be done using non-intrusive, detailed mapping of the wreck site and a 3D model 43 from which scientists can reconstruct the site in detail (Maarleveld and Guérin, 2013). | Heritage | 1777 - 1777 |

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| Organisation | Document | Quotation Content | Codes | Page |
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| IPCC | IPCC_AR6_WGII_Full_ Report | threat of heat waves across Asia, droughts in arid 6 and semi-arid areas of West, Central and South Asia, delays and weakening of the monsoon circulation in 7 South Asia, floods in monsoon regions in South, Southeast and East Asia, and glacier melting in the Hindu 8 Kush Himalaya (HKH) region (medium confidence). {10.3.1; 10.3.3} 9 10 Asian countries are experiencing a hotter summer climate, resulting in increase of energy demand for 11 cooling at a rapid rate, together with the population growth (high confidence). Decrease in 12 precipitation influences energy demand as well, as desalination, underground water pumping and 13 other energy-intensive methods are increasingly used for water supply (high confidence). More energy 14 demands in summer seasons will exceed any energy savings from relatively lower heating demand due to 15 warmer winter. Among thirteen developing countries with large energy consumption in Asia, eleven are 16 exposed to high energy insecurity and industrial systems risk (high confidence). {10.4.1} 17 18 Asian terrestrial ecosystems change is driven by global warming, precipitation and Asian monsoon 19 alteration, permafrost thawing and extreme events like dust storms along with natural and human- 20 related factors which are in interplay (high confidence). Treeline position in North Asian mountains 21 moves upward after 1990s, while in Himalaya treeline demonstrates a multidirectional shift, either moves 22 upward, or does not show upslope advance or moves downward. This can be explained by site-specific 23 complex interaction of positive effect of warming on tree growth, drought stress, change in snow 24 precipitation, land use change, especially grazing, and other factors (high confidence). The increased 25 considerably changes in biomes in Asia are a response to warming (medium confidence). Terrestrial and 26 freshwater species, populations, and communities alter in line with climate change across Asia (medium-to- 27 high confidence). Climate change, human activity, and lightning determine the increase of wildfire severity 28 and area burned in North Asia after 1990s (medium confidence). Length of plant growth season increased in 29 some parts of East and North Asia, while opposite trend or no change was observed in other parts (high 30 confidence). Observed biodiversity or habitat losses of animals or plants were linked to climate change in 31 some parts of Asia (high confidence). There are evidences that climate change can alter species interaction or 32 spatial distribution of invasive species in Asia (high confidence). Changes in ecosystems in Asia during the 33 21st century are expected to be driven by projected climatic, natural, and socioeconomic changes. Across 34 Asia, under a range of RCPs and other scenarios rising temperature is expected to contribute to northward 35 shift of biome boundaries and upward shift of mountain treeline (medium confidence). {10.4.2} 36 37 Coastal habitats of Asia are diverse and the impacts of climate change including rising temperature, 38 ocean acidification and sea level rise has brought negative effects to the services and the livelihood of 39 people depending on it (high confidence). The degree of bleaching of coral reefs was diverse among 40 different presences of stress tolerant symbionts and higher thermal thresholds. The risk of irreversible loss of 41 coral reefs, tidal marshes, seagrass meadows, plankton community and other marine and coastal ecosystems 42 increases with global warming, especially at 2°C temperature rise or more (high confidence). Mangroves in 43 the region continue to face threats due to pollution, conversion for aquaculture, agriculture, in addition to 44 climate based threats like SLR (Sea Level Rise) and coastal erosion. {10.4.3} 45 46 Both climatic and non-climatic drivers such as socio-economic changes have created water stress 47 conditions in both water supply and demand in all sub-regions of Asia (high confidence). These changes 48 in space and time directly or indirectly affected water use sectors and services. By mid-21st Century, the 49 international transboundary river basins of Amu Darya, Indus, Ganges and inter-state Sabarmati river basin 50 in India could face severe water scarcity challenges with climate change acting as a stress multiplier (high 51 confidence). Due to global warming Asian countries could experience increase of drought conditions (5- 52 20%) by the end of this century (high confidence). {10.4.4} 1 In this Report, the following summary terms are used to describe the available evidence: limited, medium, or robust; and for the degree of agreement: low, medium, or high. A level of confidence is expressed using five qualifiers: very low, low, medium, high, and very high, and typeset in italics, e.g., medium confidence. For a given evidence and agreement statement, different confidence levels can be assigned, but increasing levels of evidence and degrees of | Heritage | 1858 - 1858 |

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| Organisation | Document | Quotation Content | Codes | Page |
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| IPCC | IPCC_AR6_WGII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 10 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 10-4 Total pages: 172 1 2 The Asia glaciers are in minor area shrinkage and mass loss during 2006-2016, resulting in the 3 instability of water resource supply (high confidence). Glaciers in Asia are the water resources of about 4 220 million people in the downstream areas. The glacier meltwater in southern Tibetan Plateau has increased during 1998-2007, and will further increase till 2050. The glacier is likely2 5 to disappear by nearly 50% in 6 High Mountain Asia and about 70% in Central and Western Asia by the end of the 21st century under the 7 medium scenario, and more under the high scenario. The total amount and area of glacier lakes were found 8 increased during last decade (high confidence). More glacier collapses and surges were found in western 9 Tibet. Glacier lake outburst flood (GLOF) will threaten the securities of the local and downstream 10 communities (high confidence). Snowmelt water contributed 19% of the increase change in runoff of arid 11 region's rivers in Xinjiang, China and 10.6% of the upper Brahmaputra River during 2003-2014 (medium 12 confidence). {10.4.4; Box 10.5} 13 14 Since IPCC AR5, more studies reinforce the earlier findings on the spatial and temporal diversity of climate 15 change impacts on food production in Asia depending on the geographic location, agro ecology, and crops 16 grown, recognizing that there are winners and losers associated with the changing climate across scales (high 17 confidence). Most of these impacts have been associated with drought, monsoon rain, and oceanic oscillations, the 18 frequency and severity of which have been linked with the changing climate. Climate-related risks to agriculture 19 and food systems in Asia will progressively escalate with the changing climate, with differentiated impacts 20 across the region (medium confidence). Major projected impacts of climate change in the agriculture and 21 food sector include decline in fisheries, aquaculture, and crop production particularly in South and Southeast 22 Asia, reduction in livestock production in Mongolia, and changes in crop, farming systems and crop areas in 23 almost all regions with negative implications to food security (medium confidence). In India, rice production 24 can decrease from 10% to 30% whereas maize production can decrease from 25% to 70% assuming a range 25 of temperature increase from 1º to 4°C. Similarly, rice production in Cambodia can decrease by 45% by 26 2080 under high emission scenario. Occurrence of pests such as the golden apple snail (Pomacea 27 canaliculate), associated with the predicted increase in climatically suitable habitats in 2080, threatens the 28 top Asian rice-producing countries including China, India, Indonesia, Bangladesh, Vietnam, Thailand, 29 Myanmar, Philippines and Japan. Increasing temperatures, changing precipitation levels, and extreme 30 climate events like heat waves, droughts and typhoons will persist to be important vulnerability drivers that 31 will shape agricultural productivity particularly in South Asia, Southeast Asia, and Central Asia. {10.4.5; 32 Figure 10.6} 33 34 Asian urban areas are considered high risk locations from projected climate, extreme events, 35 unplanned urbanisation, rapid land use change (high confidence) but also sites of ongoing adaptation 36 (medium confidence). Asia is home to the largest share of people living in informal settlements, with 332 37 million in Eastern and South-Eastern Asia, 197 million in Central and Southern Asia. By 2050, 64% of 38 Asia's population will be urban. Coastal cities, especially in South and South East Asia are expected to see 39 significant increase in average annual economic losses between 2005 and 2050 due to flooding, with very 40 high losses in East Asian cities under high emission scenario (high confidence). Climate change will amplify 41 the urban heat island effect across Asian cities (especially South and East Asia) at 1.5°C and 2°C 42 temperature rise, both substantially larger than under the present climate (medium evidence, high agreement). | Heritage | 1858 - 1859 |
| IPCC | IPCC_AR6_WGII_Full_Report | 22 23 Drawing upon a greater number of studies made possible by greater use of advanced research tools such as 24 remote sensing as well as meticulous modelling of impacts, the Fifth Assessment Report could significantly 25 expand its coverage of pertinent issues (IPCC, 2014c). For example, the discussion on the Himalayas was 26 expanded to cover observed and projected impacts of climate change on tourism (see WGII AR5 Section 27 10.6.2); livelihood assets such as water and food (WGII AR5 Sections 9.3.3.1, 13.3.1.1, 18.5.3, 19.6.3); 28 poverty (WGII AR5 Section 13.3.2.3); culture (WGII AR5 Section 12.3.2); flood risks (WGII AR5 Sections 29 18.3.1.1, 24.2.1); health risks (WGII AR5 Section 24.4.6.2); and ecosystems (WGII AR5 Section 30 24.4.2.2)(IPCC, 2014c). | Heritage | 1863 - 1863 |
| IPCC | IPCC_AR6_WGII_Full_Report | 38 39 Biodiversity and ecosystem services play a critical role in socioeconomic development as well as the cultural 40 and spiritual fulfilment of the population in the Asia (IPBES, 2018). For example, species richness reaches it 41 maximum in the "coral triangle" of South-East Asia (central Philippines and central Indonesia) (IPCA, 2017) 42 and the extent of mangrove forests in Asia is about 38.7% of the global total (Bunting et al., 2018). These 43 coastal ecosystems provide multiple ecosystem services related to food production by fisheries/aquaculture, 44 carbon sequestration, coastal protection, and tourism/Recreation (Ruckelshaus et al., 2013). | Heritage | 1868 - 1868 |
| IPCC | IPCC_AR6_WGII_Full_Report | 28 29 10.4.2.1 Observed Impacts 30 31 10.4.2.1.1 Biomes and mountain treeline 32 Changes in biomes in Asia are compatible with a response to regional SAT increase (Arias et al., 2021) 33 (medium agreement, medium evidence). Expansion of the boreal forest and reduction of the tundra area is 34 observed for about 60% of latitudinal and altitudinal sites in Siberia (Rees et al., 2020). In Central Siberia, 35 the changes in climate and disturbance regimes are shifting the southern taiga ecotone northward (Brazhnik 36 et al., 2017). In Taimyr, no significant changes in the forest boundary were observed during the last three 37 decades (Pospelova et al., 2017). For the Japanese archipelago, it is suggested that tree community 38 composition change along the temperature gradient is a response to past and/or current climate changes 39 (Suzuki et al., 2015). | Heritage | 1876 - 1876 |

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| IPCC | IPCC_AR6_WGII_Full_Report | 54 In Himalaya, treeline over recent decades either moves upward (Schickhoff et al., 2015; Suwal et al., 2016; 55 Sigdel et al., 2018; Tiwari and Jha, 2018), or does not show upslope advance (Schickhoff et al., 2015; Gaire 56 et al., 2017; Singh et al., 2018c), or moves downward (Bhatta et al., 2018). In Tibetan Plateau, treeline either 57 shifted upwards or showed no significant upward shift (Wang et al., 2019c). This can be explained by site�ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 10 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 10-22 Total pages: 172 1 specific complex interaction of positive effect of warming on tree growth, drought stress, change in snow 2 precipitation, inter- and intraspecific interactions of trees and shrubs, land use change, especially grazing, 3 and other factors (Liang et al., 2014; Lenoir and Svenning, 2015; Tiwari et al., 2017; Sigdel et al., 2018; 4 Tiwari and Jha, 2018; Sigdel et al., 2020). It is largely unknown how broader scale climate inputs, as pre- 5 monsoon droughts interact with local-scale factors to govern treeline response patterns (Schickhoff et al., 6 2015; Müller et al., 2016; Bhatta et al., 2018; Singh et al., 2019b). | Heritage | 1876 - 1877 |
| IPCC | IPCC_AR6_WGII_Full_Report | 39 40 One of the probable results of global warming is rising high seas level. Scientists believe that increasing 41 greenhouse gases (earth temperature controller) is the reason of this global warming and by using satellite 42 measurements, have forecasted averagely 1-2 mm for rising high seas level (Jafari et al., 2016). The level of 43 thermal stress (based on a degree heating month index, DHMI) at these locations during the 2015–2016 El 44 Niño was unprecedented and stronger than previous ones (Lough et al., 2018) Persian Gulf the reef-bottom 45 temperatures in 2017 were among the hottest on record, with mean daily maxima averaging 35.9 ± 0.10C 46 across sites, with hourly temperatures reaching as high as 37.7o C (Riegl et al., 2018). About 94.3% of corals 47 bleached, and two-thirds of corals suffered mortality in 2017 (Burt et al., 2019). In 2018 coral cover 48 averaged just 7.5% across the southern basin of the Persian Gulf. This mass mortality did not cause dramatic 49 shifts in community composition as earlier bleaching events had removed most sensitive taxa. An exception 50 was the already rare Acropora which were locally extirpated in summer 2017 (Burt et al., 2019). During 51 2008-2011 also the coral communities of Musandam and Oman have shown changes depending on the stress 52 tolerance levels of the species and the local environmental disturbance level (Bento et al., 2016). | Heritage | 1884 - 1884 |
| IPCC | IPCC_AR6_WGII_Full_Report | 3 4 An ecosystem-based approach to managing coral reefs in the Gulf of Thailand is needed to identify 5 appropriate marine protected area networks and to strengthen marine and coastal resource policies in order to 6 build coral reef resilience (Sutthacheep et al., 2013). Scope to develop novel mitigation approaches toward 7 coral protection through the use of symbiotic bacteria and their metabolites (Motone et al., 2018); (Motone et 8 al., 2020) has been suggested. Coral culture and transplantation within the Gulf are feasible for helping 9 maintain coral species populations and preserving genomes and adaptive capacities of Gulf corals that are 10 endangered by future thermal stress events (Coles and Riegl, 2013). Greater focus on understanding the 11 flexibility and adaptability of people associated with coral reefs, especially in a time of rapid global change 12 (Hoegh-Guldberg et al., 2019) and a well-designed research program for developing a more targeted policy 13 agenda (Lam et al., 2019). is also recommended. Cutting carbon emissions (Bruno and Valdivia, 2016) and 14 limiting warming to below 1.5˚C is essential to preserving coral reefs worldwide and protecting millions of 15 people (Frieler et al., 2013) (Hoegh-Guldberg et al., 2017). Many visitors to coral reefs have high 16 environmental awareness and reef visitation can both help to fund and to encourage coral reef conservation 17 (Spalding et al., 2017). | Heritage | 1886 - 1886 |
| IPCC | IPCC_AR6_WGII_Full_Report | 35 36 Valuation of ecosystem services of mangroves indicated that they prevent more than 1.7 billion US$ in 37 damages for extreme events (1-in-50-year) in Philippines (Menéndez et al., 2018). They reduce flooding to 38 613,500 people/year, 23% of whom live below the poverty line and avert damages to 1 billion US$/year in 39 residential and industrial property. Mangroves have also become very popular as source of livelihood in Asia 40 through tourism (Dehghani et al., 2010),(Kuenzer and Tuan, 2013), (Spalding and Parret, 2019) (Dasgupta et 41 al., 2020. ) and they support fisheries (Hutchison et al., 2014). | Heritage | 1886 - 1886 |
| IPCC | IPCC_AR6_WGII_Full_Report | 7 8 The seagrass meadows are also good sinks of carbon (Fourqurean et al., 2012) capable of storing 9 19.9petagrams (Pg) organic carbon, but with very high regional and site and species variability (Ganguly et 10 al., 2017);(Stankovic et al., 2018); (Gallagher et al., 2019); (Ricart et al., 2020). As highly efficient carbon 11 sinks, these store up to 18 percent of the world's oceanic carbon and they also reduce the impacts of ocean 12 acidification (UNEP, 2020). | Heritage | 1887 - 1887 |
| IPCC | IPCC_AR6_WGII_Full_Report | 47 48 Seaweeds are important biotic resource capable of capturing carbon and used widely as food, medicine and 49 as raw material for industrial purposes. Warming and altered pH can affect seaweeds indifferent ways (Gao 50 et al., 2016); (Gao et al., 2017); (Gao et al., 2018a), (Wu et al., 2019b). Outbreak of intense blooms of 51 species like Ulva rigida (Gao et al., 2017) and Ulva prolifera (Zhang et al., 2019f) have increased due to 52 varied factors including climate change. These have created huge economic losses in Yellow sea affecting 53 local mariculture, tourism and the functioning of the coastal and marine ecosystems (Zhang et al., 2019f). | Heritage | 1887 - 1887 |

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| IPCC | IPCC_AR6_WGII_Full_Report | 19 20 Destruction by natural hazards was found to remove the above ground C pool, but the sediment C pool was 21 found to be maintained (Chen et al., 2018b). In Andaman & Nicobar islands the 2004 Indian Ocean Tsunami 22 severely impacted the mangrove habitats at the Nicobar Islands (Nehru and Balasubramanian, 2018),while 23 new inter-tidal habitats suitable for mangrove colonisation developed. Mangrove species with a wide 24 distribution and larger propagules (showed high colonisation potential in the new habitats compared to other 25 species (Nehru and Balasubramanian, 2018) Mangrove sites in Asia are predominantly minerogenic so 26 continued sediment supply is essential for the long-term resilience of Asia's mangroves to SLR (Lovelock et 27 al., 2015; Balke and Friess, 2016; Ward et al., 2016a; Ward et al., 2016b) . | Heritage | 1888 - 1888 |
| IPCC | IPCC_AR6_WGII_Full_Report | 43 44 10.4.3.4 Adaptation options 45 46 The Nations (2019) has identified establishment of protected areas, restoring ecosystems like mangroves / 47 coral reefs, integrated coastal zone management practices, sand banks and structural technologies and 48 implementing local monitoring networks for increasing adaptive capacity and protecting biodiversity of 49 coastal ecosystem. In Asia, management of marine sites by earmarking protected areas (SDG 14) has been 50 found to be low with only 27% area being protected. In India detailed climate change adaptation guideline 51 coastal protection and management has been prepared considering various environmental and social aspects 52 (Black et al., 2017). The Ocean Health Index for clean waters was also low, 54.6 and the threat to the 53 ecosystem due to combined effect of pollution and climate change was high. Table 10.2 shows the ocean and 54 Marine Protected Areas (MPA). | Heritage | 1890 - 1890 |
| IPCC | IPCC_AR6_WGII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 10 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 10-36 Total pages: 172 1 2 3 Table 10.2: Status of Ocean and MPA. Data Source: (Sachs et al., 2018) Ocean Health Index - Clean waters (0- 100) Fish stocks overexploited or collapsed (%) Ocean Health Index - Fisheries (0-100) Fish caught by trawling (%) Ocean Health Index - Biodiversity (0-100) Marine sites, mean protected area (%) Eastern Asia 54.0 29.1 49.5 39.8 89.6 32.5 South-Eastern Asia 54.1 28.5 54.9 34.7 84.6 25.0 Western Asia 54.3 28.3 46.2 20.4 89.4 18.3 Southern Asia 50.3 17.4 51.0 15.1 88.3 41.2 Northern Asia 91.6 55.4 57.6 60.0 93.4 30.0 Asia 54.6 26.9 50.3 27.3 87.9 27.0 4 5 6 Conservation and Restoration of mangrove were found to be effective tools for enhancing ecosystem carbon 7 storage and an important part of Reducing Emissions from Deforestation and forest Degradation plus 8 (REDD+ ) schemes and climate change mitigation (Ahmed and Glaser, 2016). In East Asia restoration 9 success has been attributed to right geomorphological locations (Van Cuong et al., 2015; Balke and Friess, 10 2016) and co-management models (Johnson and Iizuka, 2016; Veettil et al., 2019). | Heritage | 1890 - 1891 |
| IPCC | IPCC_AR6_WGII_Full_Report | 11 12 In South Asia, restoration programs have been largely successful (Jayanthi et al., 2018) but in some regions 13 partly a failure due to inappropriate site selection, poor post planting care and other issues (Kodikara et al., 14 2017). Using remote sensing it was observed that there are high recovery rates of mangroves in a relatively 15 short period of time (1.5 years) after a powerful typhoon indicating that natural recovery and regeneration 16 would be a more economically and ecologically viable strategy. Better mangrove management through 17 mapping is suggested (Castillo et al., 2018) (Gandhi and Jones, 2019). Statistical tools developed for 18 modelling biomass and timber volume (Phan et al., 2019) and allometric models to estimate aboveground 19 biomass and carbon stocks (Vinh et al., 2019) will be useful in estimating stocks in mangroves. Future 20 mangrove loss may be offset by increasing national and international conservation initiatives that incorporate 21 mangroves, such as the Sustainable Development Goals, Blue Carbon, and Payments for Ecosystem Services 22 (Friess et al., 2019). Since seagrass meadows and marine macroalage are important habitats capable of 23 combating impacts of climate change, the need for a global networking system with participation of stake 24 holders has been suggested (Duffy et al., 2019). | Heritage | 1891 - 1891 |
| IPCC | IPCC_AR6_WGII_Full_Report | 50 51 The impacts of permafrost changes on regional hydrology in Asia remains unclear. However, those changes 52 may alter the soil carbon storage (e.g. Nie et al., 2019) and increase the riverine carbon exports (e.g. Song et 53 al., 2019). But the fate of soil carbon within permafrost is more complicated and uncertain due to the 54 influences of heterogeneous landforms, as pointed out in China's Second National Soil Survey (Jiang et al., 55 2019). | Heritage | 1898 - 1898 |
| IPCC | IPCC_AR6_WGII_Full_Report | 56 57 [END BOX 10.4 HERE] ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 10 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 10-44 Total pages: 172 1 2 3 10.4.4.5 Climate Vulnerability and Adaptation: Interfaces and Interventions 4 5 In Asia and its diverse sub-regions, the challenge of adaptation to climate change at diverse sectors, sites and 6 scales of vulnerability in the domain of fresh water resources is compounded by the nexus between long- 7 standing non-climatic vulnerabilities and climatic impacts, both observed and projected. Water insecurities in 8 Asia are increasing due to excessive freshwater withdrawals (Satoh et al., 2017) economic and population 9 growth (Gleick and Iceland, 2018), urbanisation and peri urbanisation (Roth et al., 2019) food insecurity 10 (Demin, 2014) and lack of access to clean and safe drinking water (Cullet, 2016) which mostly affects the 11 heath of most vulnerable sections of society. | Heritage | 1898 - 1899 |
| IPCC | IPCC_AR6_WGII_Full_Report | 17 18 MHW are a new threat to fisheries and aquaculture (Froehlich et al., 2018; Frölicher and Laufkötter, 2018) 19 including disease spread (Oliver et al., 2017), live feed culture (copepods) (Doan et al., 2018), and farming 20 of finfishes like Cobia (Le et al., 2020). Predicting MHW is considered a pre-requisite for increasing the 21 preparedness of farmers (Frölicher and Laufkötter, 2018). In Southeast Asian countries more than 30% of 22 aquaculture areas are predicted to become unsuitable for production by 2050 - 2070 and aquaculture 23 production is predicted to reduce 10% - 20% by 2050 - 2070 due to climate change (Froehlich et al., 2018). | Heritage | 1903 - 1903 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 25 26 Asian farmers and fisherfolks already employ a variety of adaptation practices to minimise the adverse 27 impacts of climate change. A recent systematic and comprehensive review of farmers' adaptation practices 28 in Asia, Shaffril et al. (2018) categorised these practices into different forms such as crop management, 29 irrigation and water management, farm management, ffnancial management, physical infrastructure 30 management, and social activities. "Climate-smart agriculture" - an integrated approach for developing 31 agricultural strategies that address the intertwined challenges of food security and climate change – is 32 increasingly being promoted in many parts of the region, especially in Southeast and South Asia with 33 potentially promising outcomes (Chandra et al., 2017; Khatri-Chhetri et al., 2017; Shirsath et al., 2017; 34 Westermann et al., 2018; Wassmann et al., 2019b). Site specific adaptations such as those in Pakistan 35 include the farmers' utilisation of several adaptation techniques which include changing crop type and 36 variety and improving seed quality; fertiliser application and use of pesticides and plant shade trees; and 37 water storage and farm diversification (Fahad and Wang, 2018), as well as the implementation of a 38 comprehensive climate information services to farming communities (World Meteorological Organization, 39 2017). | Heritage | 1908 - 1908 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 39 40 There is medium evidence (low agreement) about the effectiveness of migration and planned relocation in 41 reducing risk exposure. Evidence on climate-driven internal migration shows that moving has mixed 42 outcomes on risk reduction and adaptive capacity. On one hand, migration can improve adaptive capacity by 43 increasing incomes and remittances as well as diversifying livelihoods (Maharjan et al., 2020). On the other, 44 migration can expose migrants to new risks. For example, in Bangalore (India), migrants often face high 45 exposure to localised flooding, insecure and unsafe livelihoods, and social exclusion, which collectively 46 shape their vulnerability (Byers et al., 2018);(Singh and Basu, 2020). In Metro Manila (Philippines) and 47 Chennai (India), planned relocations to reduce disaster risk have often exacerbated vulnerability, due to 48 relocation sites being in environmentally sensitive areas, inadequate livelihood opportunities, and exposure 49 to new risks (Ajibade, 2019; Jain et al., 2021) (Meerow, 2017). | Heritage | 1922 - 1922 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 39 40 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 10 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 10-72 Total pages: 172 1 2 Figure 10.11: Projected health impacts due to climate change in Asia 3 4 5 The global estimates for increases in malaria and dengue deaths (annual estimates) are approximately 32,700 6 and 280 additional deaths, respectively, in 2050 under the medium-high emissions scenario (World Health 7 Organization, 2014). Among these additional deaths, 9,300 and 200 deaths, respectively, are projected to 8 occur in South Asia. The population at risk of malaria infection is estimated to increase by 134 million by 9 2030 in South Asia under the medium-high emissions scenario, considering socio-economic development. If 10 no actions are taken, malaria incidence in northern China is projected to increase by 69%–182% by 2050 11 (Song et al., 2016). Another study suggested a decrease in climate suitability for malaria in northern and 12 eastern India, southern Myanmar, southern Thailand, the Malaysia border region, Cambodia, eastern Borneo 13 and Indonesia by 2050 (Khormi and Kumar, 2016). By contrast, climate suitability for malaria is projected to 14 increase in the southern and south-eastern mainland of China and Taiwan, Province of China (Khormi and 15 Kumar, 2016). | Heritage | 1926 - 1927 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 20 Higher numbers of dengue fever cases are projected to occur under RCP 8.5 than RCP2.6 in China (Song et 21 al., 2017). Compared with the average numbers in 1997–2012, the annual number of days suitable for 22 dengue fever transmission in the 2020s, 2050s and 2080s will increase by 15, 25 and 40 days, respectively, 23 in south China under RCP8.5. In addition, areas in which year-round dengue fever epidemics occur will likely increase by 4500, 8800 and 20,700 km2 24 in the 2020s, 2050s and 2080s, respectively, under RCP8.5 25 (Nahiduzzaman et al., 2015). | Heritage | 1927 - 1927 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 41 42 Changing dietary patterns, particularly reducing red meat consumption and increasing fruit and vegetable 43 consumption, contributes to the reduced greenhouse gas emissions, as well as premature deaths. The 44 adoption of global dietary guidelines was estimated to avoid 5.1 million deaths per year relative to the 45 reference scenario, in which the largest number of avoidable deaths occurred in East Asia and South Asia, 46 and greenhouse gas emissions would be reduced most in East Asia (Springmann et al., 2016). In China, 47 dietary shifts to meet the national dietary reference intakes reduced the daily carbon footprint by 5-28% 48 depending on scenario (Song et al., 2017). In India, the optimised healthy diets (e.g., lower amounts of 49 wheat, and increased amounts of legumes) could help reduce up to 30% water use per person for irrigation 50 and reduce diet-related greenhouse gas emissions. This would result in 6,800 life-years gained per 100,000 51 population in 2050 (Milner et al., 2017). | Heritage | 1928 - 1928 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 47 48 A study of Sylhet Division in Bangladesh, deploying knowledge quality assessment' (KQA) tool found 49 significant co-relation between a narrow technocratic problem framing, divorced from traditional knowledge 50 strongly rooted in local socio-cultural histories and relatively low project success due to skewed risk-based 51 calculation disconnected to the ground realities (Wani and Ariana, 2018) (Haque et al., 2017) while 52 highlighting the vulnerability of the Bajo tribal communities, inhabiting the coastal areas of Indonesia, to 53 climate change, share several examples of their Indigenous Knowledge and traditions of marine resource 54 conservation, and show how this wisdom, a valuable asset for climate adaptation governance, has been 55 passed from generation to generation through oral tradition. | Heritage | 1931 - 1931 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 32 33 10.5.2.2.4 Forests and Biodiversity 34 Technologies and its applications to identify habitat degradation, ecosystem functions and biodiversity 35 conservation are increasing in Asia, with many countries looking up to new and improved means for forest 36 and biodiversity monitoring and conservation. In particular, there has been an impressive use of temporal 37 satellite data, particularly from the Landsat and the MODIS series for widespread monitoring of forests and 38 ecological resources. These provided reliable information on forests and ecosystem services at country level, 39 in difficult terrains, such as the mountains, cross-boundaries and otherwise inaccessible areas. For instance, 40 Yin et al. (2017) estimated cross-boundary forest resources in Central Asia using remote sensing techniques, 41 a region which traditionally suffered from lack of reliable forest data. In a separate study, Reddy et al. (2020) 42 used long-term MODIS forest fire data from 2003–2017 to characterise fire frequency, density, and hotspots 43 in South Asia. Archival of scientific data, particularly helped the provisioning of scientific research, backed 44 by the state-of-the art modelling techniques, advance-computing methods and innovations in big data 45 analysis. A number of studies simulated forest futures from local to continent scale under different socio- 46 economic and climate scenarios. As for instance, at local scale, DasGupta et al. (2018) projected future 47 extent of mangroves in the Sundarban delta under four local scenarios, while Estoque et al. (2019) modelled 48 and developed spatial maps of regional forest futures in Southeast Asia using the five SSP scenarios. Science 49 and technology also helped the monitoring of species diversity and abundance, pivotal for sustaining 50 ecosystem and ecosystem based adaptation. Digital camera traps, radio-collaring methods have largely 51 replaced old film cameras and labour-intensive methods of photo-screening to count target species (Pimm et 52 al., 2015). This enhanced scientific capacities to monitor biodiversity and facilitate better conservation in 53 difficult terrains, control poachers and maintain steady ecological balance. Umapathy et al. (2016), for 54 example used VHF radio-collars and satellite-based tracking tools to monitor the movement of Bengal tigers 55 in hostile island terrain. Photo recognition and other non-invasive techniques for individual identification 56 have been rising in Asia. For example, a study by Gray et al. (2014) used fecal-DNA samples to estimate the 57 population density of Asian elephant in Cambodia. The advancement of citizen science programs has greatly ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 10 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 10-82 Total pages: 172 1 facilitated better monitoring of forest resources, including invasive floral and faunal species (Chandler et al., 2 2017; Johnson et al., 2020). In Asia, citizen science has been used effectively in India (Chandler et al., 3 2017), also in Malaysia for the monitoring the urban bird abundance (Puan et al., 2019). | Heritage | 1936 - 1937 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 7 8 Way forward: Developing robust metrics and institutions for measuring and reporting L&D at national and 9 regional scales, especially non-economic damages and L&D due to slow-onset events is critical. In addition 10 to vulnerability assessments, assessing L&D and limits to adaptation can inform adaptation prioritisation and 11 enhance adaptation effectiveness (e.g.(Craft and Fisher, 2016) (Leiter et al., 2019)). Lessons are available 12 from biodiversity and ecosystem services monitoring frameworks that have well-developed metrics and 13 processes (e.g., (Díaz et al., 2020)). | Heritage | 1944 - 1944 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 28 29 Risks are generally amplified for people without social protection or essential infrastructure and services, 30 and for people with limited access to land and quality housing, especially those in exposed areas and 31 informal settlements without secure tenure (ESCAP, 2017). Stateless people are disproportionately affected 32 by climate change and disasters as they tend to reside in hazard-prone areas and their statues as non-citizens 33 often limits access to assistance (Connell, 2015). The three main types of social protection, namely (i) social 34 safety nets (also known as social assistance), which include conditional and unconditional cash transfers, 35 public work programs, subsidies, and food stamps; (ii) social insurance, which consists of contributory 36 pensions and contributory health insurance; and (iii) labour market measures, which include instruments 37 such as unemployment compensation (Bank, 2018b). The potential for an integrated adaptive social 38 protection is not yet harnessed by policymakers in tackling the structural causes of vulnerability to climate 39 change (Tenzing, 2019). Public works program, i.e. India's MGNREGA should take into account climate 40 risk in planning and support development of community assets to increase collective resilience. | Heritage | 1948 - 1948 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 33 This will have major implications for SP systems and therefore national SP strategies should be designed to 34 anticipate and address climate-induced internal mobility (Schwan and Yu, 2017). For instance, it does not 35 offer a solution for maintaining Indigenous culture often strongly affected or even disrupted by climate 36 change (Olsson, 2014). Hence, an effective approach needs to combine different policy instruments to 37 support protection, adaptation and migration (O'Brien et al., 2018). | Heritage | 1949 - 1949 |
| IPCC | IPCC_AR6_WGII_Full_ Report | (Mistry and Berardi, 2016; Roder et al., 2016) ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 10 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 10-98 Total pages: 172 from the perspective of Indigenous Knowledge and then seeking relevant scientific knowledge Empowering younger generation to ensure continuity of Indigenous cultures and theirlinked ecosystems. | Heritage | 1952 - 1953 |

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| IPCC | IPCC_AR6_WGII_Full_Report | (2020) in Philippines Carefully planned resettlement and migration (including decongestion of urban areas) Inadequate evidence to make an assessment SDGs 8, 10, 11 SDGs 6, 10, 11 (Arnall, 2019) in Asia; (Maharjan et al., 2020) in South Asia; (Estoque et al., 2020) in the Philippines; Banerjee et al. (2019) in Nepal Aquifer storage and recovery Low synergy SDGs 6, 12 (Lopez et al., 2014) in Saudi Arabia; (Hoque et al., 2016) in South and SE Asia Nature-based solutions in urban areas: green infrastructure (including urban green space, blue-green infrastructure) High synergy Blue-green infrastructure act as carbon sinks SDGs 3, 9, 11 (Mabon et al., 2019) in Japan; (Estoque et al., 2020) in the Philippines; (Byrne et al., 2015) and (Zhang et al., 2020a) in China; (Mabon and Shih, 2018) in Taiwan, Province of China; (Liao, 2019) and (Radhakrishnan et al., 2019) in Singapore Coastal green infrastructure High synergy SDGs 9, 11, 13, 14, 15 (Sovacool et al., 2012), (Chow, 2018) and (Zinia and McShane, 2018) in Bangladesh; (Koh and ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 10 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 10-100 Total pages: 172 Teh, 2019) and (Herbeck and Flitner, 2019) in SE Asia; (Giffin et al., 2020) in Asia 1 Table Notes: a 2 Expert judgement b 3 Climate change adaptation options in the agricultural sector include soil management, crop diversification, cropping 4 system optimisation, and management, water management, sustainable land management, crop pest and disease 5 management, and direct seeding of rice (Aryal et al., 2020b). Other specific agricultural practices that have adaptation 6 and mitigation synergies include between tillage and residue management, alternate wetting and drying, site-specific 7 nutrient management, crop diversification to less water-intensive crops such as maize, and improved livestock 8 management (Aryal et al., 2020a). c 9 Risk management strategies in agriculture include crop insurance, index insurance, social networking and 10 community-based adaptation, collective international action, and integrated agro-meteorological advisory services 11 (Aryal et al., 2020b). | Heritage | 1954 - 1955 |
| IPCC | IPCC_AR6_WGII_Full_Report | 11 12 10.6.2.3 Knowledge Gaps 13 14 Adaptation follows knowledge on risks, and literature exists that systematically identifies and characterises 15 exposure and vulnerability, but gaps still exist. Decision making under uncertainty is challenged by the lack 16 of data for adapting to current and uncertain future climate, the different perceptions of risk, and the potential 17 solutions across different cultures and languages (van der Keur et al., 2016). Lack of downscaled climatic 18 data, diverse institutional structures, and missing links in policies, are among the challenges in South Asia 19 (Mall et al., 2019). In agriculture, there are gaps in the use of advanced farming techniques such as drought- 20 resistant crops, and information on climate change to support farming households in making adaptation 21 decisions (Akhtar et al., 2019; Khanal et al., 2019; Ullah et al., 2019). Better understanding of effective 22 water management is crucial due to conflicts for shared water in ARA (Shaban and Hamze, 2017; UNDP, 23 2018). For delta regions, gaps identified are methodologies and approaches appropriate for understanding 24 social vulnerability at various scales, pathways required for adaptation policy and response in the deltas that 25 transcend development, and the lessons from implemented policy and how practice can build on these 26 lessons in the deltas, among others (Lwasa, 2015). Approaches in tackling the challenges of climate change 27 and disasters in the cities of developing countries could be better understood, and shared between cities so 28 they can learn from one another (Filho et al., 2019). | Heritage | 1957 - 1957 |
| IPCC | IPCC_AR6_WGII_Full_Report | 17 18 Asia exhibits tremendous variation in terms of ecosystems, economic development, cultures, and climate risk 19 exposure. Mirroring this variation, households, communities, and governments have a wide range of coping 20 and adaptation strategies to deal with changing climatic conditions, with co-benefits for various non-climatic 21 issues such as poverty, conflict, and livelihood dynamics. | Heritage | 1961 - 1961 |
| IPCC | IPCC_AR6_WGII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 10 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 10-161 Total pages: 172 1 Song, G. et al., 2017: Dietary changes to mitigate climate change and benefit public health in China. Science of The 2 Total Environment, 577, 289-298, doi:https://doi.org/10.1016/j.scitotenv.2016.10.184. | Heritage | 2015 - 2016 |
| IPCC | IPCC_AR6_WGII_Full_Report | 33 Nuisance and extreme coastal flooding have increased due to sea-level rise superimposed upon high tides 34 and storm surges in low-lying coastal and estuarine locations, including impacts on cultural sites, traditions 35 and lifestyles of Aboriginal and Torres Strait Islander Peoples in Australia and Tangata Whenua Māori in 36 New Zealand. Droughts have caused financial and emotional stress in farm households and rural 37 communities. Tourism has been negatively affected by coral bleaching, fires, poor ski seasons and receding 38 glaciers. Governments, business and communities have experienced major costs associated with extreme 39 weather, droughts and sea-level rise. {11.3, 11.4, 11.5.2, Table 11.2, Boxes 11.1-11.6} 40 41 Climate impacts are cascading and compounding across sectors and socio-economic and natural 42 systems (high confidence). Complex connections are generating new types of risks, exacerbating existing 43 stressors and constraining adaptation options. An example is the impacts that cascade between 44 interdependent systems and infrastructure in cities and settlements. Another example is the 2019-2020 south- 45 eastern Australian wildfires which burned 5.8 to 8.1 million hectares, with 114 listed threatened species 46 losing at least half of their habitat and 49 losing over 80%, over 3,000 houses destroyed, 33 people killed, a 47 further 429 deaths and 3230 hospitalizations due to cardiovascular or respiratory conditions, $1.95 billion in 48 health costs, $2.3 billion in insured losses, and $3.6 billion in losses for tourism, hospitality, agriculture and 49 forestry. {11.5.1, Box 11.1} 50 51 Increasing climate risks are projected to exacerbate existing vulnerabilities and social inequalities and 52 inequities (high confidence). These include inequalities between Indigenous and non-Indigenous Peoples, 53 and between generations, rural and urban areas, incomes and health status, increasing the climate risks and 54 adaptation challenges faced by some groups and places. Resultant climate change impacts include the 55 displacement of some people and businesses, and threaten social cohesion and community wellbeing. | Heritage | 2030 - 2030 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 15 16 Australia's economy is dominated by financial and insurance services, education, mining, construction, 17 tourism, health care and social assistance (ABS, 2018) with Australian exports accruing mostly from mining 18 (ABS, 2018; ABS, 2019). In New Zealand, service industries, including tourism, collectively account for 19 around two thirds of GDP (NZ Treasury, 2016). The primary sector contributes 6% of New Zealand's GDP 20 and over half of the country's export earnings (NZ Treasury, 2016). | Heritage | 2034 - 2034 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 11 12 13 14 Figure 11.1: Observed temperature changes in Australia and New Zealand. Annual temperature change time-series are 15 shown for 1910–2019. Mean annual temperature trend maps are shown for 1960–2019 using contours for Australia and 16 individual sites for New Zealand. Data courtesy of BoM and NIWA. | Heritage | 2037 - 2037 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 17 18 19 20 Figure 11.2: Observed rainfall changes in Australia and New Zealand. Rainfall change time-series for 1900–2019 are 21 shown for northern Australia (December-February: DJF), southwest Australia (June-August: JJA) and southeast ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 11 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 11-11 Total pages: 151 1 Australia (JJA). Dashed lines on the maps for Australia show regions used for the time-series. Rainfall trend maps are 2 shown for 1960–2019 (DJF and JJA) using contours for Australia and individual sites for New Zealand. Areas of low 3 Australian rainfall (less than 0.25 mm/day) are shaded white in JJA. Data courtesy of BoM and NIWA. | Heritage | 2037 - 2038 |
| IPCC | IPCC_AR6_WGII_Full_ Report | Sea surface temperature Increased by 0.2°C/decade from 1981–2018. (MfE, 2020a) Air temperature extremes Number of frost days (below 0 degrees Celsius) decreased at 12 of 30 sites, the number of warm days (over 25°C) increased at 19 of 30 sites, and the number of heatwave days increased at 18 of 30 sites during 1972–2019. Increase in the frequency of hot February days exceeding the 90th percentile between 1980– 1989 and 2010–2019, with some regions showing more than a five-fold increase. | Heritage | 2040 - 2040 |
| IPCC | IPCC_AR6_WGII_Full_ Report | (NIWA, 2019; Salinger et al., 2019b; Salinger et al., 2020; Oliver et al., 2021) Rainfall From 1960–2019, almost half of the 30 sites had an increase in annual rainfall (mostly in the south) and 10 sites (mostly in the north) had a decrease, but few of the trends are statistically significant. Rainfall increased by 2.8% per decade in Whanganui, 2.1% per decade in Milford Sound and 1.3% per decade in Hokitika. Rainfall decreased by 4.3% per decade in Whangarei and 3.2% per decade in Tauranga. | Heritage | 2040 - 2040 |
| IPCC | IPCC_AR6_WGII_Full_ Report | (MfE, 2020a) Rainfall extremes The number of days with extreme rainfall increased at 14 of 30 sites and decreased at 11 sites from 1960–2019. Most sites with increasing annual rainfall had more extreme rainfall and most sites with decreasing annual rainfall had less extreme rainfall. | Heritage | 2040 - 2040 |
| IPCC | IPCC_AR6_WGII_Full_ Report | (MfE, 2020a) Drought Drought frequency increased at 13 of 30 sites from 1972–2019 and decreased at 9 sites. Drought intensity increased at 14 sites, 11 of which are in the north, and decreased at 9 sites, 7 of which are in the south. | Heritage | 2040 - 2040 |
| IPCC | IPCC_AR6_WGII_Full_ Report | (MfE, 2020a) Windspeed Since 1970, the wind belt has often been shifted to the south of New Zealand, bringing an overall decrease in wind-speed over the country. For 1980–2019, the annual maximum wind gust decreased at 11 of the 14 sites that had enough data to calculate a trend, and increased at 2 of the 14 sites (MfE, 2020a) Sea-level rise Increased 1.8 mm/year from 1900–2018 and 2.4 mm/year from 1961–2018, mostly due to climate change. | Heritage | 2040 - 2040 |
| IPCC | IPCC_AR6_WGII_Full_ Report | (Bell and Hannah, 2019) Fire Six of 28 sites (Napier, Lake Tekapo, Queenstown, Gisborne, Masterton, and Gore) had an increase in days with very high or extreme fire danger from 1997–2019 and 6 sites (Blenheim, Christchurch, Nelson, Tara Hills, Timaru, and Wellington) had a decrease. An increase in fire impacts from 1988–2018 included homes lost, damaged, threatened and evacuated. | Heritage | 2040 - 2040 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | induced canopy dieback across a range of forest and woodland types (e.g. northern jarrah) (Matusick et al., 2018; Hoffmann et al., 2019) Multiple wildfires in short succession resulting from increased fire risk conditions including declining winter rainfall and increasing hot days Local extirpations and replacement of dominant canopy tree species and replacement by woody shrubs due to seeders having insufficient time to reach reproductive age (Alpine Ash) or vegetative regeneration capacity is exhausted (Snow Gum woodlands) (Slatyer, 2010; Bowman et al., 2014; Fairman et al., 2016; Harris et al., 2018; Zylstra, 2018) Background warming and drying created soil and vegetation conditions that are conducive to fires being ignited by lightning storms in regions that have rarely experienced fire over the last few millennia Death of fire sensitive trees species from unprecedented fire events (Palaeo-endemic pencil pine forest growing in sphagnum, Tasmania, killed by lightning-ignited fires in 2016) (Hoffmann et al., 2019) Australia Alps Bioregion and Tasmanian alpine zones Severe winter drought; warming and climate-induced biotic interactions Shifts in dominant vegetation with a decline in grasses and other graminoids and an increase in forb and shrub cover in Bogong High Plains, Victoria, Australia (Bhend et al., 2012; Hoffmann et al., 2019) ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 11 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 11-21 Total pages: 151 Snow loss, fire, drought and temperature changes Changing interactions within and among three key alpine taxa related to food supply and vegetation habitat resources: The mountain pygmy-possum (Burramys parvus), the mountain plum pine (Podocarpus lawrencei) and the bogong moth (Agrostis infusia) (Hoffmann et al., 2019) Retreat of snow line Increased species diversity in alpine zone (Slatyer, 2010) Reduced snow cover Loss of snow-related habitat for alpine zone endemic and obligate species (ACE CRC, 2010; Pepler et al., 2015a; Thompson, 2016; Mitchell et al., 2019) Wet Tropics World Heritage Area Warming and increasing length of dry season Some vertebrate species have already declined in both distribution area and population size, both earlier and more severely than originally predicted (Moran et al., 2014; Hoffmann et al., 2019) Sub-Antarctic Macquarie island Reduced summer water availability for 17 consecutive summers, and increases in mean wind speed, sunshine hours and evapotranspiration over four decades Dieback in the critically endangered habitat-forming cushion plant Azorella macquariensis in the fellfield and herb field communities (Bergstrom et al., 2015; Hoffmann et al., 2019) Mass mortality of wildlife species (flying foxes, freshwater fish) Extreme heat events; rising water temperatures, temperature fluctuations, altered rainfall regimes including droughts and reduced in-flows flying foxes - thermal tolerances of species exceeded; fish - amplified extreme temperature fluctuations, increasing annual water basin temperatures, extreme droughts and reduced runoff after rainfall (AAS, 2019; Ratnayake et al., 2019; Vertessy et al., 2019) Bramble Cay melomys (mammal) Melomys rubicola Sea-level rise and storm surges in Torres Strait Loss of habitat and global extinction (Lunney et al., 2014; Gynther et al., 2016; Waller et al., 2017; CSIRO, 2018) Koala, Phascolarctos cinereus Increasing drought and rising temperatures, compounding impacts of habitat loss, fire and increasing human population Population declines and enhanced risk of local extinctions (Lunney et al., 2014) Tawny dragon lizard, Ctenophorus decresii Desiccation stress driven by higher body temperatures and declining rainfall Population decline and potential local extinction in Flinders Ranges, South Australia (Walker et al., 2015) ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 11 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 11-22 Total pages: 151 Birds Changing thermal regimes including increasing thermal stress and changes in plant productivity are identified causal Changes in body size, mass and condition and other traits linked to heat exchange (Gardner et al., 2014a; Gardner et al., 2014b; Campbell-Tennant et al., 2015; Gardner et al., 2018; Hoffmann et al., 2019) New Zealand Forest Birds Warming Increasing invasive predation pressure on endemic forest birds surviving in cool forest refugia, particularly larger�bodied bird species that nest in tree cavities and are poor dispersers (Walker et al., 2019) Coastal ecosystems More severe storms and rising sea levels Erosion of coastal habitats | Heritage | 2047 - 2049 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 22 23 Improved coastal modelling, experiments and in situ studies are reducing uncertainties at a local scale about 24 the impact of future sea-level rise on coastal freshwater terrestrial wetlands (medium confidence) (Shoo et 25 al., 2014; Bayliss et al., 2018; Grieger et al., 2019). Low-lying coastal wetlands are susceptible to saltwater 26 intrusion from sea-level rise (Shoo et al., 2014; Kettles and Bell, 2015; Finlayson et al., 2017) with 27 consequences for species dependent on freshwater habitats (Houston et al., 2020). Saline habitat conditions 28 will move inland and new coastal ecosystem states may emerge, including the World Heritage listed 29 Kakadu's freshwater wetland (Bayliss et al., 2018) (Table 11.5). Increasingly, sea-level rise will shrink the 30 intertidal zone, having implications for wading birds which use this zone (Tait and Pearce, 2019) (Box 11.6). | Heritage | 2050 - 2050 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 32 33 The Australian wildfires of 2019–2020 resulted in 33 deaths, over 3,000 houses destroyed, $2.3 billion in 34 insured losses, and $3.6 billion in losses for tourism, hospitality, agriculture and forestry (CoA, 2020e; 35 Filkov et al., 2020) (Figure Box 11.1.2). Smoke caused a further 429 deaths and 3230 hospitalizations as a 36 result of respiratory distress and illness, with health costs totalling $1.95 billion (Johnston et al., 2020). | Heritage | 2055 - 2055 |
| IPCC | IPCC_AR6_WGII_Full_ Report | Communications Clearer communication of existing exposure and vulnerability to enable informed decisions about risk tolerance and management. This should include sites of key biodiversity that are sensitive or susceptible to fire. | Heritage | 2058 - 2058 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 16 17 The marine environment is important to the culture, health and well-being of the region's diverse Indigenous 18 Peoples, including those who had sovereign ownership, governance, resource rights, and stewardship over 19 'Sea Country' for many thousands of years before the current sea level stabilised approximately 6000 years 20 ago and before current coastal ecosystems were established (Rist et al., 2019). Marine environments ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 11 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 11-32 Total pages: 151 1 contribute A$69 billion per year to Australia's economy (Eadie et al., 2011), and NZ$4 billion per year to 2 New Zealand's economy (MfE, 2016). They have a high proportion of rare and endemic species (Croxall et 3 al., 2012) and provide ecosystem services including food production, coastal protection, tourism and carbon 4 sequestration (Croxall et al., 2012; Kelleway et al., 2017). Half of the species within New Zealand's seas are 5 endemic (Costello et al., 2010b). | Heritage | 2058 - 2059 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 35 36 In 2016 and 2017, the Great Barrier Reef (GBR) experienced consecutive occurrences of the most severe 37 coral bleaching in recorded history (very high confidence) (Box 11.2), with shallow-water reef in the top two 38 thirds of the GBR affected and the severity of bleaching on individual reefs tightly correlated with the level 39 of local heat exposure (Hughes et al., 2018b; Hughes et al., 2019c). Mass mortality of corals from these two 40 unprecedented events resulted in larval recruitment in 2018 declining by 89% compared to historical levels 41 (Hughes et al., 2019b). Southern reefs were also affected by warming, although significantly less than in the 42 north (Kennedy et al., 2018). Coral reefs in Australia are at very high risk of continued negative effects on 43 ecosystem structure and function (Hughes et al., 2019b) (very high confidence), cultural well-being 44 (Goldberg et al., 2016; Lyons et al., 2019) (very high confidence), food provision (Hoegh-Guldberg et al., 45 2017) (medium confidence), coastal protection (Ferrario et al., 2014) (high confidence) and tourism (Deloitte 46 Access Economics, 2017; Prideaux and Pabel, 2018; GBRMPA, 2019) (high confidence). If bleaching 47 persists, an estimated 10,000 jobs and A$1 billion in revenue would be lost per year from declines in tourism 48 alone (Swann and Campbell, 2016). | Heritage | 2059 - 2059 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 49 50 11.3.2.2 Projected Impacts 51 52 Future ocean warming, coupled with periodic extreme heat events, is projected to lead to the continued loss 53 of ecosystem services and ecological functions (high confidence) (Smale et al., 2019), as species further shift 54 their distributions and/or decline in abundance (Day et al., 2018). Compounding climate-driven changes in 55 the distribution of habitat forming species, invasive macroalgae are predicted to exhibit higher growth under 56 all higher pCO2 and lower pH conditions (Roth-Schulze et al., 2018). Corals and mangroves around northern 57 Australia and kelp and seagrass around southern Australia are of critical importance for ecosystem structure ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 11 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 11-33 Total pages: 151 1 and function, fisheries productivity, coastal protection and carbon sequestration; these ecosystem services are therefore extremely likely2 2 to decline with continued warming. Equally, many species provide important 3 ecosystem structure and function in New Zealand's seas including in the deep sea (Tracey and 4 Hjorvarsdottir, 2019). The future level of sustainable exploitation of fisheries is dependent on how climate 5 change impacts these ecosystems. Native kelp is projected to further decline in south-eastern New Zealand 6 with warming seas (Table 11.6). Climate change could affect New Zealand fisheries' productivity 7 (Cummings et al., 2021), and both ocean warming and acidification may directly affect shellfish culture 8 (Cunningham et al., 2016; Cummings et al., 2019), and indirectly through changes in phytoplankton 9 production (Pinkerton, 2017). | Heritage | 2059 - 2060 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 43 44 11.3.2.3 Adaptation 45 46 Climate change adaptation opportunities and pathways have been identified across aquaculture, fisheries, 47 conservation and tourism sectors in the region (MacDiarmid et al., 2013; Fleming et al., 2014; MPI, 2015; 48 Jennings et al., 2016; MfE, 2016; Royal Society Te Apārangi, 2017; Ling and Hobday, 2019) and some 49 stakeholders are already autonomously adapting (Pecl et al., 2019). Some fishing and aquaculture industries 50 use seasonal forecasts of environmental conditions, to improve decision making, risk management, and 51 business planning (Hobday et al., 2016) with potential to use 5-yearly forecasts similarly (Champion et al., 52 2019). Shifts in the distribution, and availability of target species (e.g., oceanic tuna) would impact the 2 In this Report, the following summary terms are used to describe the available evidence: limited, medium, or robust; and for the degree of agreement: low, medium, or high. A level of confidence is expressed using five qualifiers: very low, low, medium, high, and very high, and typeset in italics, e.g., medium confidence. For a given evidence and agreement statement, different confidence levels can be assigned, but increasing levels of evidence and degrees of agreement are correlated with increasing confidence. | Heritage | 2060 - 2060 |
| IPCC | IPCC_AR6_WGII_Full_ Report | Loss of kelp Australia-wide totalling at least 140,187 ha Ocean warming & change in East Australian Current (lower nutrients) (Wahl et al., 2015; Butler et al., 2020; Filbee-Dexter and Wernberg, 2020) Regional loss of seagrass in Shark Bay World Heritage Area, Western Australia High air and water temperatures during 2011 heatwave (Strydom et al., 2020) Increased annual dugong and inshore dolphin mortality across Queensland Sustained low air temperature and increased freshwater discharge during high SOI (ENSO) index (Meager and Limpus, 2014) Predict equatorward decline and poleward shift of sea urchin in eastern Australia Ocean warming (Castro et al., 2020) Increasing mortality of Australian fur seal pups in low-lying colonies Storm surges and high tides amplified by ongoing sea�level rise (McLean et al., 2018) (Box 11.6) Rapid shifts in community composition, structure and integrity Community-wide tropicalization in Australian temperate reef communities. Temperate species replaced by seaweeds, invertebrates, corals, and fishes characteristic of subtropical and tropical waters Extreme marine heatwaves led to a 100-km range contraction of extensive kelp forests (Vergés et al., 2016; Wernberg et al., 2016) On-going declines in habitat-forming seaweeds Dieback of temperate seagrass in Shark Bay, Australia, subsequently replaced by a tropical early successional seagrass with seagrass�associated megafauna (sea turtles) declining in health status Climate-driven shift of tropical herbivores 2011 Marine heatwave (Thomson et al., 2015; Nowicki et al., 2017; Zarco�Perello et al., 2017) (Wernberg et al., 2016) (Strydom et al., 2020) Increased herbivory by fish on tropicalized reefs of Western Australia Change in species composition due to ocean warming (Zarco-Perello et al., 2019) No recovery two years after coral bleaching and macro alga mortality in western Australia 2011 marine heatwave (Bridge et al., 2014) ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 11 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 11-37 Total pages: 151 Mass mortality of particular coral species on affected reefs during heatwaves on the Great Barrier Reef (eastern Australia) led to altered coral reef structure and species composition 8 months later. | Heritage | 2063 - 2064 |

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| IPCC | IPCC_AR6_WGII_Full_Report | 2016 marine heatwave 2016 Marine heatwave (Hughes et al., 2018c) (Stuart-Smith et al., 2018) New Zealand Changes in life-history Alteration of the shell of pāua (black footed abalone, Haliotis iris) under lowered pH (calcite layer thinner, greater etching of external shell surface) Decline in maximum swimming performance of kingfish and snapper Increased mortality and faster growth in juvenile kingfish Lowered pH (experimental laboratory study) Elevated CO2 (experimental laboratory study) Increased temperature (Cummings et al., 2019) (Watson et al., 2018; McMahon et al., 2020) (Watson et al., 2018) Earlier spawning of snapper in South Island 2017–2018 heatwave (Salinger et al., 2019b) Increase in mortality Heat stress mortality in salmon farms off Marlborough, New Zealand, where 20 % of the salmon stocks died 2017–18 marine heatwave (Salinger et al., 2019b) Changes in species distributions Species increasingly caught further south, e.g. snapper and kingfish Ocean warming and 2017–2018 marine heatwave (Salinger et al., 2019b) Non-breeding distribution of New Zealand nesting seabird (Antarctic Prion) shifting south with long term climate inferred from stable isotopes Climate warming (Grecian et al., 2016) Less phytoplankton production in Tasman Sea but more on subtropical front Ocean warming (Chiswell and Sutton, 2020) Loss of bull kelp (Durvillaea) populations in southern New Zealand subsequently replaced by the introduced kelp Undaria 2017-18 heatwave when sea and air temperatures exceeded 23 and 30 ° C respectively (Salinger et al., 2019b; Thomsen et al., 2019; Salinger et al., 2020) 1 2 3 [START BOX 11.2 HERE] 4 5 Box 11.2: The Great Barrier Reef in Crisis 6 7 The Great Barrier Reef ("GBR") is the world's largest coral reef system, comprising 3,863 reefs over an area of 348,700 km2 8 , stretching for 2,300 km. The GBR is a central cornerstone of the beliefs, knowledges, Lores, 9 languages and ways of living for over 70 geographically and culturally diverse Traditional Owner groups ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 11 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 11-38 Total pages: 151 1 spanning the length of the GBR (Dale et al., 2018), and contributes an estimated A$6.4 billion per year (pre 2 COVID) to the Australian economy, mainly via tourism. As the world's most extensive coral reef ecosystem, 3 GBR is a globally outstanding and significant entity, with practically the entire ecosystem inscribed as World 4 Heritage in 1981 (UNESCO, 2021). | Heritage | 2064 - 2065 |
| IPCC | IPCC_AR6_WGII_Full_Report | 41 42 Tourist motivations for visiting the GBR are changing, with a recent survey finding that two-thirds of 43 tourists were visiting 'before it was gone' and a similar number were reporting damage to the reef – an 44 example of 'last chance tourism' (Piggott-McKellar and McNamara, 2016). The Australian Government is 45 investing A$1.9 billion to support the Great Barrier Reef through science and practical environmental 46 outcomes including reducing other anthropogenic pressures which can suppress natural adaptive capacity 47 (CoA, 2019b; GBRMPA, 2019). However, adaptation efforts on the Great Barrier Reef aimed specifically at 48 climate impacts, for example, coral restoration following marine heatwave impacts (Boström-Einarsson et 49 al., 2020) may slow the impacts of climate change in small discrete regions of the reef, or reduce short-term 50 socio-economic ramifications, but will not prevent widespread bleaching (Condie et al. 2021). | Heritage | 2065 - 2065 |
| IPCC | IPCC_AR6_WGII_Full_Report | 33 34 11.3.4.1.2 Projected impacts 35 Australian crop yields are projected to decline due to hotter and drier conditions, including intense heat 36 spikes (Anwar et al., 2015; Lobell et al., 2015; Prokopy et al., 2015; Dreccer et al., 2018; Nuttall et al., 2018; 37 Wang et al., 2018a) (high confidence). Interactions of heat and drought could lead to even greater losses than 38 heat alone (Sadras and Dreccer, 2015; Hunt et al., 2018). Australian wheat yields are projected to decline by 39 2050, with a median yield decline of up to 30% in south-west Australia and up to 15% in South Australia, 40 with possible increases and decreases in the east (Taylor et al., 2018, Wang, #1599; Wang et al., 2018a). In 41 temperate fruit, accumulated winter chill for horticulture is projected to further decline (Darbyshire et al., 42 2016). Winegrape maturity is projected to occur earlier due to warmer temperatures (Webb et al., 2014; van 43 Leeuwen and Darriet, 2016; Jarvis et al., 2018; Ausseil et al., 2019b) (high confidence) leading to potential 44 changes in wine style (Bonada et al., 2015). Rice is susceptible to heat stress and average grain yield losses 45 across rice varieties range from 83% to 53% in experimental trials when heat stress was applied during plant 46 emergence and grain fill stages (Ali et al., 2019). In Tasmania, wheat yields are projected to increase, 47 particularly at sites presently temperature-limited (Phelan et al., 2014). | Heritage | 2074 - 2074 |
| IPCC | IPCC_AR6_WGII_Full_Report | 26 27 Key infrastructure and services face major challenges. Structural metal corrosion rates are projected to 28 increase significantly at coastal locations but decrease inland (Trivedi et al., 2014). A drier climate may 29 decrease the rate of deterioration of road pavements but extreme rainfall events and heat pose a significant 30 risk (Taylor and Philp, 2015), especially to unsealed roads in northern Australia (CoA, 2015). Critical 31 infrastructure on coasts is at risk from sea-level rise and storm surges (Box 11.6). Facilities such as hospitals 32 face weather-related hazards exacerbated by climate change and not originally anticipated in building and 33 infrastructure design (Loosemore et al., 2011; Loosemore et al., 2014). By 2050, increased risks are 34 projected for the availability and quality of potable water supplies, delivery of wastewater and stormwater 35 services to communities, transport systems, electricity infrastructure, operating municipal landfills, and 36 contaminated sites located near rivers and the coast (Gilpin et al., 2020; MfE, 2020a; Hughes et al., 2021). | Heritage | 2081 - 2081 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | Sector Key Risks Adaptation Options Inter-Sector Dependencies Sources Road Heat; sea-level rise; coastal surges; floods and high intensity rainfall impacts on road foundations Re-routing; coastal protection; improved drainage Ports (fuel supply); rail (fuel supply); electricity (NCCARF, 2013; CoA, 2018a; MfE, 2020a) Rail Extreme temperatures; flooding; sea-level rise; high intensity rainfall impacts on track foundations Drainage and ventilation improvements; systematic risk assessments; overhead wire and rail/sleeper upgrades; rerouting Electricity; telecommunications; fuel supply (transport, ports) (CoA, 2018a; MfE, 2020a) Urban and Rural Built Environment1 Extreme temperatures; floods; extreme weather events; wildfire (at urban-rural interface); sea-level rise Multiple options from the building-to-city scale to reduce heat impacts and improve climate resilience; behavioural change; coastal defences and managed retreat Road; rail; electricity; air and seaports; telecommunications; water and wastewater (CoA, 2018a; Newton et al., 2018; Haddad et al., 2019; MfE, 2020a; Paulik et al., 2020; Tapper, In Press) (Box 11.4) (Box 11.4) ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 11 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 11-56 Total pages: 151 Electricity High wind/ temperature events; wildfire; lightning; dust storms; drought (hydro) Demand management; re-engineering and new technology; network intelligence; smart metering; improved planning for outages Road; rail; water (CoA, 2017; MfE, 2020a) (11.3.10.) Ports: Air and Sea Sea-level rise; coastal surges; wind; heat; extreme weather events Air; improved coastal, pluvial and fluvial flood protection, on�site services. Sea; widening operational limits, raising wharfs, roads and breakwaters. | Heritage | 2082 - 2083 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 32 33 34 [START BOX 11.6 HERE] 35 36 Box 11.6: Rising to the Sea-Level Challenge 37 38 Many of the region's cities and settlements, cultural sites and place attachments are situated around harbours, 39 estuaries and lowland rivers (Black, 2010; PCE, 2015; Australia SoE, 2016; Rouse et al., 2017; Hanslow et 40 al., 2018; Birkett-Rees et al., 2020) exposed to ongoing relative sea-level rise (RSLR). RSLR includes 41 regional variability in oceanic conditions (Zhang et al., 2017) and vertical land movement along New 42 Zealand's tectonically dynamic coasts (Levy et al., 2020) and some Australian hotspots for subsidence 43 (Denys et al., 2020; King et al., 2020; Watson, 2020). | Heritage | 2084 - 2084 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 44 45 46 Table Box 11.6.1: Observed and projected impacts from higher mean sea level Impacts from increase in mean sea level References Nuisance and extreme coastal flooding have increased from higher mean sea level in New Zealand. Projected sea level rise will cause more frequent flooding in Australia and New Zealand before mid-century (very high confidence) (Hunter, 2012; McInnes et al., 2016; Stephens et al., 2017; Stephens et al., 2020) (Steffen et al., 2014; PCE, 2015; MfE, 2017a; Hague et al., 2019; Paulik et al., 2020) Squeeze in intertidal habitats (high confidence) (Steffen et al., 2014; Peirson et al., 2015; Mills et al., 2016a; Mills et al., 2016b; Pettit et al., 2016; Rouse et al., 2017; Rayner et al., 2021) ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 11 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 11-58 Total pages: 151 Significant property and infrastructure damage (high confidence) (Steffen et al., 2014; PCE, 2015; Harvey, 2019; LGNZ, 2019; Paulik et al., 2020) (Table Box 11.5.2) (Table Box 11.6.2) Loss of significant cultural and archaeological sites and projected to compound with several hazards over this century (medium confidence) (Bickler et al., 2013; Birkett-Rees et al., 2020; NZ Archaeological Association, 2020) Increasing flood risk and water insecurity with health and well�being impacts on Torres Strait Islanders (high confidence) (Steffen et al., 2014; McInnes et al., 2016; McNamara et al., 2017) Degradation and loss of freshwater wetlands (high confidence) (Pettit et al., 2016; Bayliss and Ligtermoet, 2018; Tait and Pearce, 2019; Grieger et al., 2020; Swales et al., 2020) 1 2 3 Coastal shoreline position is driven by a complex combination of natural drivers, past and present human 4 interventions, climate variability (Bryan et al., 2008; Helman and Tomlinson, 2018; Allis and Murray Hicks, 5 2019) and variation in sediment flux (Blue and Kench, 2017; Ford and Dickson, 2018). RSLR, to date, is a 6 secondary factor influencing shoreline stability (medium confidence), and in Australia no definitive sea-level 7 rise signature is yet observed in shoreline recession, nor documented in New Zealand, due to variability in 8 shoreline position responding to storms and seasonal, annual and decadal climate drivers (Australian 9 Government, 2009; McInnes et al., 2016; Sharples et al., 2020). | Heritage | 2084 - 2085 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 17 18 11.3.7 Tourism 19 20 11.3.7.1 Observed Impacts 21 22 Tourism is a major economic driver in the region, accounting for 3% (Australia) and 6% (New Zealand) of 23 GDP pre-COVID-19 (WTTC, 2018). Climate change is having significant impacts on tourism due to the 24 heavy reliance of the sector on natural heritage and outdoor attractions (11.3.1; Box 11.2). Furthermore, as 25 Australia and New Zealand are both long-haul destinations, a global increase in 'flygskam' (flight shame) 26 will to impact travel patterns (Becken et al., 2021). | Heritage | 2090 - 2090 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 27 28 Impacts of climate change are being observed across the tourism system (Scott et al., 2019a) (high 29 confidence), most notably the Great Barrier Reef (Box 11.2) (Ma and Kirilenko, 2019). Australia's ski 30 industry is very sensitive to climatic change, due to reduction in snow depth and the length of the snow 31 season (Table 11.2) (Steiger et al., 2019; Knowles and Scott, 2020). The 2019-2020 summer wildfires (Box 32 11.1), impacted tourism and travel infrastructure, affecting air quality, vineyards and wineries (CoA, 2020e; 33 Filkov et al., 2020). Global media coverage of the wildfires, alongside Australia's climate change policy 34 response, profoundly and negatively, affected Australia's destination image (Schweinsberg et al., 2020; Wen 35 et al., 2020). In New Zealand's South Island, Fox and Franz Josef Glaciers have retreated approximately 36 700m since 2008, with ice melt and retreat resulting in increased rock fall risks and negatively affecting the 37 tourist experience (Purdie, 2013; Stewart et al., 2016; Wang and Zhou, 2019). The West Coast of New 38 Zealand is extremely prone to flooding events impacting amenity values and access (Paulik et al., 2019b). | Heritage | 2090 - 2090 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 39 Damage to tracks, huts and bridges have closed popular destinations, including the Hooker Glacier and the 40 popular Routeburn and Heaphy Tracks during heavy rainfall events (Christie et al., 2020). Climate-driven 41 damage is motivating 'last chance' tourism to see key natural heritage and outdoor attractions, e.g. Great 42 Barrier Reef (Piggott-McKellar and McNamara, 2016) and Franz and Fox Glaciers (Stewart et al., 2016). | Heritage | 2090 - 2090 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 43 44 11.3.7.2 Projected Impacts 45 46 Widespread impacts from projected climate change are very likely across the tourism sector. The World 47 Heritage listed Kakadu National Park in Australia is projected to experience increasing severity of cyclones 48 (Turton, 2014) and sea-level rise is projected to affect freshwater wetlands (11.3.1.2; Table 11.5) (McInnes 49 et al., 2015) and Indigenous rock art (Higham et al., 2016; Hughes et al., 2018a). The projected increase in 50 the number of hot days in northern and inland Australia may impact the attractiveness of the region for 51 tourists (Amelung and Nicholls, 2014; Webb and Hennessy, 2015). Coastal erosion and flooding of 52 Australasian beaches due to sea-level rise and intensifying storm activity is estimated to increase by 60% on 53 the Sunshine Coast by 2030 causing significant damage to tourist-related infrastructure (Hughes et al., 54 2018a). Urgent 'hard' and 'soft' adaptation strategies are projected to help reduce sea-level rise impacts 55 (Becken and Wilson, 2016). | Heritage | 2090 - 2090 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 56 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 11 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 11-64 Total pages: 151 1 Glacier tourism, a multimillion-dollar industry in New Zealand, is potentially under threat because glacier 2 volumes are projected to decrease (Purdie, 2013) (very high confidence). Glacier volume reductions of 50– 3 92% by 2099 relative to present reflect the large range of temperature projections between RCP2.6 and 4 RCP8.5. Under RCP2.6 at 2099, the glaciers retain a similar configuration to present, although clean-ice 5 glaciers will retreat significantly. For RCP4.5, RCP6.0 and RCP8.5, the clean-ice glaciers will retreat to 6 become small remnants in the high mountains (Anderson et al. 2021). | Heritage | 2090 - 2091 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 7 8 Snow skiing faces significant challenges from climate change (high confidence). In Australia, the annual 9 maximum snow depth is estimated to decrease from current levels by 15% (2030) and 60% by 2070 (SRES 10 A2) (Di Luca et al., 2018). By 2070-2099, relative to 2000-2010, the length of the Victorian ski-season is 11 projected to contract by 65-90% under RCP8.5 (Harris et al., 2016). The New Zealand tourism destination of 12 Queenstown is expected to experience declining snowfall, increased wind and more severe weather events 13 (Becken and Wilson, 2016). Ski tourism stakeholders have been responding to longer-term climate risks with 14 an increase in snow-making machines in New Zealand since 2013 (Hopkins, 2015) and in Australia (Harris 15 et al., 2016). | Heritage | 2091 - 2091 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 25 26 With the exception of the ski industry (Becken, 2013; Hopkins, 2015), tourism stakeholders generally focus 27 on coping with short-term weather events, rather than longer-term climate risks, but do exhibit high adaptive 28 capacity by diversifying their activities (Stewart et al., 2016). Post Covid-19 pandemic economics and 29 recovery policies challenge this sector's prospects, and the combination of COVID-19 and climate change 30 (e.g. fires, floods) has also highlighted the need for the tourism sector to be able to respond to multiple, 31 overlapping crises. | Heritage | 2091 - 2091 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 32 33 There is limited evidence that research into the impact of climate change on tourism in Australia and New 34 Zealand is translating into policy or action (Moyle et al., 2017). New Zealand government tourism sector 35 strategies acknowledge this and the need for greater understanding of climate change for the sector, (TIA, 36 2019), but do not offer solutions (MBIE, 2019b; MfE, 2020a). The COVID-19 pandemic and the global 37 pause of international travel offers an opportunity to potentially 'reset' tourism to account for the impacts of 38 climate change (Prideaux et al., 2020). | Heritage | 2091 - 2091 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 26 Climatic extremes increase the risk and impact of spillages along transportation routes (Grech et al., 2016) 27 exacerbate mining's effects on hydrology, ecosystems, and air quality (Phillips, 2016; Ali et al., 2018); 28 increase contamination risks (Metcalfe and Bui, 2016); and disrupt and slow mine site rehabilitation 29 (Wardell-Johnson et al., 2015; Hancock et al., 2017). Adaptations such as improved water management are 30 emerging slowly (Gasbarro et al., 2016; Becker et al., 2018). Some companies are spatially diversifying and 31 relocating (Hodgkinson et al., 2014). Others are replacing workers with automation and remote operations 32 (Halteh et al., 2018; Keenan et al., 2019). | Heritage | 2093 - 2093 |

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| Organisation | Document | Quotation Content | Codes | Page |
|---|---|---|---|---|
| IPCC | IPCC_AR6_WGII_Full_ Report | Impact Source Mass bleaching of the Great Barrier Reef in 2016/2017 due to a marine heatwave Box 11.2 In the New Zealand Southern Alps, extreme glacier mass loss was at least six times more likely in 2011, and ten times more likely in 2018, due to warming 11.2.1, 11.3.3 In the Australian Alps bioregion, loss of habitat for endemic and obligate species due to snow loss and increases in fire, drought and temperature Table 11.4 In the Australian wet tropics world heritage area, some vertebrate species have declined in distribution area and population size due to increasing temperatures and length of dry season Table 11.4 Extinction of Bramble Cay melomys due to loss of habitat caused by storm surges and sea�level rise in Torres Strait Table 11.4 In New Zealand, increasing invasive predation pressure on endemic forest birds surviving in cool forest refugia due to anthropogenic warming Table 11.4 In New Zealand, erosion of coastal habitats due to more severe storms and sea-level rise Table 11.4, Box 11.6 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 11 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 11-69 Total pages: 151 In Australia, estuaries warming and freshening with decreasing pH Table 11.6 Changes in life-history traits, behaviour or recruitment of fish and invertebrates due to ocean acidification or warming, severe decline in recruitment of coral on the Great Barrier Reef due to ocean warming, aquaculture stock deaths due to heat stress Table 11.6 New diseases and toxins due to warming and extension of East Australian Current Table 11.6 Changes in almost 200 marine species distributions and abundance due to ocean warming Table 11.6 Temperate marine species replaced by seaweeds, invertebrates, corals and fishes characteristic of subtropical and tropical waters Table 11.6 River flow decline in southern Australia is largely due to the decline in cool season rainfall partly attributed to anthropogenic climate change 11.3.3 In New Zealand, the 2007/08 drought and the 2012/13 drought were 20% attributed to anthropogenic climate change 11.3.3 In New Zealand, about 30% of the insured damage for the 12 costliest flood events from 2007-2017 can be attributed to anthropogenic climate change 11.3.8 In Australia, 35-36% of heat-related excess mortality in Melbourne, Sydney and Brisbane from 1991-2018 can be attributed to anthropogenic climate change 11.3.6 1 2 3 11.4 Indigenous Peoples 4 5 Indigenous perspectives of well-being embrace physical, social, emotional and cultural domains, 6 collectiveness and reciprocity, and more fundamentally connections between all elements across the past, 7 present and future generations (Australia. NAHS Working Party, 1989; MfE, 2020a). Changing climate 8 conditions are expected to exacerbate many of the social, economic and health inequalities faced by 9 Aboriginal and Torres Strait Islander Peoples in Australia and Māori in New Zealand (Bennett et al., 2014; 10 Hopkins et al., 2015; AIHW, 2016; Lyons et al., 2019) (high confidence). As a consequence, effective policy 11 responses are those that take advantage of the interlinkages and dependencies between mitigation, adaptation 12 and Indigenous Peoples' wellbeing (Jones, 2019) and those that address the transformative change needed 13 from colonial legacies (Hill et al., 2020) (high confidence). There is a central role for Indigenous Peoples in 14 climate change decision making that helps address the enduring legacy of colonisation through building 15 opportunities based on Indigenous governance regimes, cultural practices to care for land and water, and 16 intergenerational perspectives (Nursey-Bray et al., 2019; Petzold et al., 2020) (Cross-Chapter Box INDIG in 17 Chapter 18) (very high confidence). | Heritage | 2095 - 2096 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 18 19 11.4.1 Aboriginal and Torres Strait Islander Peoples of Australia 20 21 The highly diverse Aboriginal and Torres Strait Islander Peoples of Australia have survived and adapted to 22 climate changes such as sea-level rise and extreme rainfall variability during the late Pleistocene era, through 23 intimate place-based Indigenous Knowledge in practice and while losing traditional land and sea Country 24 ownership (Liedloff et al., 2013) (Cross-Chapter-Box INDIG in Chapter 18) including during the Late 25 Pleistocene era (Golding and Campbell, 2009; Nunn and Reid, 2016). They belong to the world's oldest 26 living cultures, continually resident in their own ancestral lands, or 'country', for over 65,000 years 27 (Kingsley et al., 2013; Marmion et al., 2014; Nagle et al., 2017; Tobler et al., 2017; Nursey-Bray and 28 Palmer, 2018). The majority of the Australian Indigenous Peoples live in urban areas in southern and eastern 29 Australia, but are the predominant population in remote areas. | Heritage | 2096 - 2096 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 30 31 Climate-related impacts on Aboriginal and Torres Strait Islander Peoples, Countries (traditional estates) and 32 cultures have been observed across Australia and are pervasive, complex and compounding(Green et al., 33 2009) (11.5.1) (high confidence). For example, loss of bio-cultural diversity, nutritional changes through 34 availability of traditional foods and forced diet change, water security, and loss of land and cultural resources 35 through erosion and sea-level rise (Table 11.10) ](TSRA, 2018). Moreover, these impacts are being 36 experienced now particularly in low-lying geographical areas- especially in the Torres Strait Islands (Mosby, ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 11 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 11-70 Total pages: 151 1 2012; Kelly, 2014; Murphy, 2019; Hall et al., 2021). Estimates of the loss from fire impacts on ecosystem 2 services that contribute to the wellbeing of remotely-located Indigenous Australians were found to be higher 3 than the financial impacts from the same fires on pastoral and conservation lands (Sangha et al., 2020) and 4 could increase with both financial and non-financial impacts (Box 11.1). | Heritage | 2096 - 2097 |
| IPCC | IPCC_AR6_WGII_Full_ Report | IPAs can avoid the potential for 'nature–cultures dualism' that locks out Indigenous access in some protected area legislation, as they are based on relational values informed by local Indigenous Knowledge (Lee, 2016) Fire management using cultural practices can achieve greenhouse gas emission targets while also maintaining Indigenous cultural heritage. | Heritage | 2098 - 2098 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 14 15 Māori have long-term interests in land and water and are heavily invested in climate sensitive sectors 16 (agriculture, forestry, fishing, tourism and renewable energy) (King et al., 2010). Large proportions of 17 collectively owned land already suffer from high rates of erosion (Warmenhoven et al., 2014; Awatere et al., 18 2018) which are projected to be exacerbated by climate change induced extreme rainfalls (RSNZ, 2016; 19 Awatere et al., 2018) (high confidence). Changing drought occurrence, particularly across eastern and 20 northern New Zealand, is also projected to affect primary sector operations and production (King et al., 21 2010; Smith et al., 2017; Awatere et al., 2018) (medium confidence). Further, many Māori-owned lands and 22 cultural assets such as marae and urupa are located on coastal lowlands vulnerable to sea-level rise impacts 23 (Manning et al., 2014; Hardy et al., 2019) (high confidence). Māori tribal investment in fisheries and 24 aquaculture faces substantial risks from changes in ocean temperature and acidification, and the downstream 25 impacts for species distribution, productivity and yields (Law et al., 2016) (medium confidence). A clearer 26 understanding of climate change risks and the implications for sustainable outcomes can enable more 27 informed decisions by tribal organisations and governance groups. | Heritage | 2099 - 2099 |
| IPCC | IPCC_AR6_WGII_Full_ Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 11 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 11-73 Total pages: 151 1 2 3 Table 11.12: Climate-related impacts and risks for Tangata Whenua New Zealand Māori Impact Risks Changes in drought occurrence and extreme weather events Risks to Māori tribal investment in forestry, agriculture and horticulture sector operations and production, particularly across eastern and northern New Zealand (King et al., 2010; Awatere et al., 2018; Hardy et al., 2019)(medium confidence) Changes in rainfall, temperature, drought, extreme weather events and ongoing sea-level rise Risks to potable water supplies (availability and quality) for remote Māori populations (RSNZ, 2016; Henwood, 2019)(medium confidence) Changes in rainfall, temperature, drought, extreme weather events and ongoing sea-level rise Risks of exacerbating existing inequities (e.g. health, economic, education and social services), social cohesion and well-being (Bennett et al., 2014; Jones et al., 2014)(medium confidence) Changes in rainfall regimes and more intense drought combined with degradation of lands and water Risks to the distribution and survival of cultural keystone flora and fauna, as well as cascading risks for Māori customary practice, cultural identity and well-being (King et al., 2010; RSNZ, 2016; Bond et al., 2019)(high confidence) Changes in ocean temperature and acidification Risks to nearshore and ocean species productivity and distribution, as well as cascading risks for Māori tribal investment in the fisheries and aquaculture sectors (King et al., 2010; Law et al., 2016)(medium confidence) Sea-level rise induced erosion, flooding and saltwater intrusion Risks to Māori-owned coastal lands and economic investment as well as risks to community wellbeing from displacement of individuals, families and communities (Manning et al., 2014; Smith et al., 2017; Hardy et al., 2019)(high confidence) Sea-level rise induced erosion, inundation and saltwater intrusion Risks to Māori cultural heritage as well as cascading risks for tribal identity and spiritual well-being (King et al., 2010; Manning et al., 2014; RSNZ, 2016)(medium confidence) Impacts of climate change, adaptation and mitigation actions Risks that governments are unable to uphold Māori interests, values and practices under the Treaty of Waitangi, creating new, modern-day breaches of the Treaty of Waitangi (Iorns Magallanes, 2019; MfE, 2020a)(high confidence) 4 5 6 11.5 Cross-Sectoral and Cross-Regional Implications 7 8 The impacts and adaptation processes described in sections 11.3 and 11.4 are focused on specific sectors, 9 systems and Indigenous Peoples. Added complexity, risk and adaptation potential stem from cross-sectoral 10 and cross-regional inter-dependencies. | Heritage | 2099 - 2100 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 52 53 The intangible costs of climate impacts - including death and injury, impacts on health and wellbeing, 54 education and employment, community connectedness, and the loss of ancestral lands, cultural sites and 55 ecosystems (Barnett et al., 2016; Warner et al., 2019) - affect multiple sectors and systems and exacerbate 56 existing vulnerabilities. While often incommensurable, intangible costs may be far higher than the tangible 57 costs. For example, following the Victorian fires in 2009, the tangible costs were A$3.1 billion while the ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 11 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 11-76 Total pages: 151 1 intangible costs were A$3.4 billion; following the Queensland floods in 2010/11, the tangible costs were 2 A$6.7 billion while the intangible costs were A$7.4 billion (Deloitte, 2016). | Heritage | 2102 - 2103 |
| IPCC | IPCC_AR6_WGII_Full_ Report | For 0.5 m SLR, the value of buildings in New Zealand exposed to coastal inundation could increase by NZ$12.75 billion and the current 1-in-100 year flood in Australia could occur several times a year. For 1.0 m SLR, the value of exposed assets in New Zealand would be NZ$25.5 billion. For 1.1 m SLR, the value of exposed assets in Australia would be A$164- 226 billion. This would be associated with displacement of people, disruption and reduced social cohesion, degraded ecosystems, loss of cultural heritage and livelihoods, and loss of traditional lands and sacred sites. | Heritage | 2107 - 2107 |
| IPCC | IPCC_AR6_WGII_Full_ Report | Exposure: Population growth, new and infill urbanization, tourism developments in low�lying coastal areas. Buildings, roads, railways, electricity and water infrastructure. Torres Strait Island and remote Māori communities are particularly exposed and sensitive. | Heritage | 2107 - 2107 |

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| IPCC | IPCC_AR6_WGII_Full_Report | 8. Cascading, compounding and Consequences: Widespread and pervasive damage and disruption to human activities generated by interdependencies and interconnectedness of physical, social and natural ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 11 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 11-82 Total pages: 151 aggregate impacts on cities, settlements, infrastructure, supply-chains and services due to extreme events (high confidence) (11.2, 11.3.4, 11.3.5, 11.3.6, 11.3.7, 11.3.8, 11.3.9, 11.3.10, 11.4, 11.5.1, Boxes 11.1, 11.4, 11.6) systems. Examples include: Failure of transport, energy and communication infrastructure and services, heat-stress, injuries and deaths, air pollution, stress on hospital services, damage to agriculture and tourism, insurance loss from heatwaves and fires; failure of transport, stormwater and flood-control infrastructure and services from floods and storms; water restrictions, reduced agricultural production, stress for rural communities, mental health issues, lack of potable water from droughts; damage to buildings, roads, railways, electricity and water infrastructure, loss of assets and lives, displacement of people, reduced social cohesion, and degraded ecosystems from extreme sea-level rise. Large aggregate costs due to lost productivity and major disaster relief expenditure, creating unfunded liabilities and supply chain disruption, e.g., the 2019-2020 Australian fires cost A$8 billion. | Heritage | 2108 - 2109 |
| IPCC | IPCC_AR6_WGII_Full_Report | Exposure: Highly populated areas, rural and remote settlements, traditional lands and sacred sites. Greater urban density and population growth increases exposure in high-risk areas. Different exposure for different hazards, e.g. heatwaves: urban and peri-urban areas; fire: peri-urban areas and settlements near forests; floods: people, property and infrastructure from pluvial floods in cities and settlements and fluvial floods on floodplains; storms: buildings and infrastructure in cities and settlements. | Heritage | 2109 - 2109 |
| IPCC | IPCC_AR6_WGII_Full_Report | 6 7 Some businesses have initiated active adaptation (Aldum et al., 2014; Linnenluecke et al., 2015; Bremer and 8 Linnenluecke, 2017; CCATWG, 2017; MfE, 2018) with most focused on identifying climate risks (Aldum et 9 al., 2014; Gasbarro et al., 2016; Cradock-Henry, 2017). Businesses are more likely to engage in anticipatory 10 adaptation when the frequency of climate events is known (McKnight and Linnenluecke, 2019). Effective 11 cooperation and a positive innovation culture can contribute to the collaborative development of climate 12 change adaptation pathways (Bardsley et al., 2018) (medium confidence). | Heritage | 2114 - 2114 |
| IPCC | IPCC_AR6_WGII_Full_Report | FINAL DRAFT Chapter 12 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 12-4 Total pages: 181 1 2 Changes in timing and magnitude of precipitation and extreme temperatures are impacting 3 agricultural production (high confidence). Since the mid-20th century, increasing mean precipitation has 4 positively impacted agricultural production in Southeast South America, although extremely long dry spells 5 have become more frequent affecting the economies of large cities in southeast Brazil. Inversely, reduced 6 precipitation and altered rainfall at the start and end of the rainy season and during the mid-summer drought 7 is impacting rainfed subsistence farming particularly in the Dry Corridor in Central America and in the 8 tropical Andes compromising food security (high confidence). The crop growth duration for maize for those 9 regions was reduced by at least 5% between 1981-2010 and 2015-2019. {12.3.1, 12.3.2, 12.3.6, Table 12.4} 10 11 Climate change affects the epidemiology of climate-sensitive infectious diseases in the region (high 12 confidence). Examples are the effects of warming temperatures on increasing the suitability of transmission 13 of vector-borne diseases, including endemic and emerging arboviral diseases such as dengue fever, 14 chikungunya, and Zika (medium confidence). The reproduction potential for the transmission of dengue 15 increased between 17% and 80% for the period 1950-54 to 2016-2021 depending on the subregion as a result 16 of changes in temperature and precipitation (high confidence). {12.3.1, 12.3.2, 12.3.3, 12.3.5, 12.3.6, Table 17 12.1} 18 19 The Andes, northeast Brazil and the northern countries in Central America are among the more 20 sensitive regions to climatic-related migrations and displacements, a phenomenon that has increased 21 since AR5 (high confidence). Climatic drivers interact with social, political, geopolitical and economical 22 drivers; the most common climatic drivers for migration and displacements are droughts, tropical storms and 23 hurricanes, heavy rains and floods (high confidence). {12.3.1.4, 12.3.2.4, 12.3.3.4, 12.3.5.4, 12.5.8.4} 24 25 The impacts of climate change are not of equal scope for men and women (high confidence). Women, 26 particularly the poorest, are more vulnerable and are impacted in greater proportion. Often they have less 27 capacity to adapt, further widening structural gender gaps (high confidence). {12.3.7.3, 12.5.2.4, 12.5.2.5, 28 12.5.7.3, 12.5.8.1, 12.5.8.3, 12.5.8.4} 29 30 Current adaptation responses: 31 32 Ecosystem-based adaptation is the most common adaptation strategy for terrestrial and freshwater 33 ecosystems (high confidence). There is a focus on the protection of native terrestrial vegetation through 34 implementation of protected areas and payment for ecosystem services, especially those related to water 35 provision. The adaptation measures in place, however, are insufficient to safeguard terrestrial and freshwater 36 ecosystems in the CSA from negative impacts of climate change (high confidence). {12.5.1, 12.5.3, 12.6} 37 38 Adaptation initiatives in ocean and coastal ecosystems mainly focus on conservation, protection and 39 restoration) (high confidence). The main adaptation measures are ocean zoning, the prohibition of 40 productive activities (e.g., fisheries, aquaculture, mining, tourism) on marine ecosystems, the improvement 41 of research and education programs, and the creation of specific national policies (high confidence). {12.5.2} 42 43 Adaptive water management has mainly centred on enhancing quantity and quality of water supply, 44 including large infrastructure projects, which, however, are often contested and can exacerbate water 45 related conflicts (high confidence). Inclusive water regimes that overcome social inequalities and 46 approaches including nature-based solutions, such as wetland restoration and water storage and infiltration 47 infrastructure, with synergies for ecosystem conservation and disaster risk reduction, have been found to be 48 more successful for adaptation and sustainable development (high confidence). {12.5.3, 12.6.1, 12.6.3} 49 50 Adaptation strategies for agricultural production are increasing in the region as a response to current 51 and projected changes in climate (high confidence). The main observed adaptation strategies in agriculture 52 and forestry are soil and water management conservation, crop diversification, climate-smart agriculture, 53 early warning systems, upward shifting for plantations to avoid warming habitat and pests and improved 54 management of pastures and livestock. Adaptation requires governance improvements and new strategies to 55 address changing climate; nevertheless, barriers limiting adaptive capacity persist such as lack of educational 56 programs for farmers, adequate knowledge of site-specific adaptation and institutional and financial 57 constraints (high | Heritage | 2181 - 2183 |

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| Organisation | Document | Quotation Content | Codes | Page |
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| IPCC | IPCC_AR6_WGII_Full_ Report | 56 other drivers in perceived productivity changes. Index insurance builds resilience and contributes to ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 12 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 12-7 Total pages: 181 1 adaptation both by protecting farmers' assets in the face of major climate shocks, by promoting access to 2 credit, and by the adoption of improved farm technologies and practices. {12.5.4} 3 4 Institutional instability, fragmented services and poor water management, inadequate governance 5 structures, insufficient data and analysis of adaptation experience are barriers to address the water 6 challenges in the region (high confidence). {12.5.3} 7 8 Inequality, poverty and informality shaping cities in the region increase vulnerability to climate 9 change while policies, plans or interventions addressing these social challenges with inclusive 10 approaches are opportunities for adaptation (high confidence). Initiatives to improve informal and 11 precarious settlement, guaranteeing access to land and decent housing, are aligned with comprehensive 12 adaptation policies that include development and reduction of poverty, inequality and disaster risk (medium 13 confidence). {12.5.5, 12.5.7} 14 15 Adaptation policies often address climate impact drivers, but seldom include the social and economic 16 underpinnings of vulnerability. This narrow scope limits adaptation results and compromises their 17 continuity in the region (high confidence). In a context of unaddressed underdevelopment, adaptation 18 policies tackling poverty and inequality are marginal, underfunded, and not clearly included at national, 19 regional or urban levels. Dialogue and agreement including multiple actors are mechanisms to acknowledge 20 trade-offs and promote dynamic, site-specific adaptation options (medium confidence). {12.5.7} 21 22 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 12 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 12-8 Total pages: 181 1 12.1 Introduction 2 3 12.1.1 The Central and South America Region 4 5 Central and South America (CSA) is a highly diverse region, both culturally and biologically. It harbours one 6 of the highest biodiversity on the planet (Hoorn et al., 2010; Zador et al., 2015; IPBES, 2018a) (Cross- 7 Chapter Paper 1: Biodiversity Hotspots) and a wealth of cultural diversity resulting from more than 800 8 Indigenous Peoples who share the territory with European and African descendants and more recent Asian 9 migrants (CEPAL, 2014). Moreover, it is one of the most urbanized regions in the world, with some of the 10 most populated metropolitan areas (UNDESA, 2019). Several countries in the region have experienced 11 sustained economic growth in the last decades, making important advances in reducing poverty in the area. | Heritage | 2184 - 2186 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 54 55 Observed changes in streamflow and water availability affect vulnerable regions (WGII AR5 Chapter 27, 56 Magrin et al., 2014). Glacier mass changes in the Andes over the past decades are among the most negative 57 ones worldwide (SROCC Chapter 2, Hock et al., 2019). This reduction has modified the frequency, ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 12 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 12-12 Total pages: 181 1 magnitude and location of related natural hazards, while the exposure of people and infrastructure has 2 increased because in relation with growing population, tourism and economic development (high confidence) 3 (SROCC Chapter 2, Hock et al., 2019). | Heritage | 2189 - 2190 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 40 41 12.3.4 South America Monsoon (SAM) Sub-region 42 43 12.3.4.1 Hazards 44 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 12 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 12-24 Total pages: 181 1 Temperature extremes have likely increased in the intensity and frequency of hot extremes and decrease in 2 the intensity and frequency of cold extremes (Donat et al., 2013; Bitencourt et al., 2016) (WGI AR6 Table 3 11.13) (Seneviratne et al., 2021). In a vast transition zone between the Amazon and the Cerrado Biomes 4 within the region, analysis of seasonal precipitation trends suggested that almost 90% of the observational 5 sites showed reduced in the length of the rainy season in the region (Debortoli et al., 2015), on a period from 6 1971 to 2014 (Marengo et al., 2018), confirming the growth in length of the dry season. Changes in the 7 hydrological and precipitation regimes, characterized by reduction in rainfall in Southern Amazonia, 8 contrasting to an increase in the northwest Amazonia, and overall increases in extreme precipitation and in 9 the frequency of Consecutive Dry Days, is being reported by several authors (Fu et al., 2013; Almeida et al., 10 2017; Marengo et al., 2018; Espinoza et al., 2019a) with low confidence (WGI AR6 Table 11.14; 11 Seneviratne et al., 2021) due to insufficient data coverage and trends in available data generally not 12 significant. | Heritage | 2201 - 2202 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 47 48 Studies with terrestrial animals show that habitat loss increases the vulnerability of species to climate change 49 (high confidence) (de Oliveira et al., 2012; Arnan et al., 2018; da Silva et al., 2018b). NES' coral reefs have 50 shown some resilience to bleaching, but vulnerability is intensified by the synergism between chronic heat 51 stress caused by increased sea surface temperature (Teixeira et al., 2019) and other well-documented 52 stressors, such as coastal runoff, urban development, marine tourism, overexploitation of reef organisms and 53 oil extraction (high confidence) (Figure 12.8; Leão et al., 2016). | Heritage | 2207 - 2207 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 16 17 18 12.4 Key Impacts and Risks 19 20 This section synthesizes key risks across the Central and South America CSA region. It follows the 21 definition and concept of risk provided in AR5, distinguishing the risk components, climatic hazard, 22 exposure and vulnerability of people and assets (IPCC, 2014). This concept is further developed in AR6, 23 defining key risks as potentially severe risks (Section 16.5). Key risks may refer to present or future 24 conditions, with a focus on the 21st century. Both mitigation and adaptation can moderate the extent or 25 severity of risks. The identification and evaluation of risks imply socio-cultural values, which may vary 26 across individuals, communities or cultures. | Heritage | 2222 - 2222 |

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| IPCC | IPCC_AR6_WGII_Full_Report | 7. Risk to coral reef ecosystems due to coral bleaching ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 12 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 12-47 Total pages: 181 Degradation and possible death of the Mesoamerican coral reef, the second largest reef in the world. Severe damage to habitat for marine species, degrading coastal protection and other ecosystem services, decreased food security from fisheries, lack of income from tourism. | Heritage | 2224 - 2225 |
| IPCC | IPCC_AR6_WGII_Full_Report | Continued exposure to increased atmospheric $CO_2$ levels and sea surface temperatures together with destruction from coastal development, fishing practices and tourism. | Heritage | 2225 - 2225 |
| IPCC | IPCC_AR6_WGII_Full_Report | Increased number of people, infrastructure and services (coastal tourism) exposed; need of relocation of millions of people. | Heritage | 2225 - 2225 |
| IPCC | IPCC_AR6_WGII_Full_Report | Poor planning in coastal development and infrastructure, disproportionate vulnerability and limited adaptation options for rural communities and Indigenous Peoples, increasing urbanisation in coastal cities. Large economic losses and unemployment from declining tourism. | Heritage | 2225 - 2225 |
| IPCC | IPCC_AR6_WGII_Full_Report | 12 13 Rural communities in the Cusco Region, Peru, ground their ability to adapt to climate change on four 14 cultural values, known in Quechua as ayni (reciprocity), ayllu (collectiveness), yanantin (equilibrium) and 15 chanincha (solidarity), but policies oriented towards “modernization” undermine these traditional 16 mechanisms. Adaptation strategies could benefit from integrating these and other insights from traditional 17 cultures, fostering risk reduction and transformational adaptation towards intrinsically sustainable systems 18 (medium confidence: medium evidence, high agreement) (Walshe and Argumedo, 2016). | Heritage | 2231 - 2231 |
| IPCC | IPCC_AR6_WGII_Full_Report | 45 46 12.5.2 Ocean and Coastal Ecosystems and their Services 47 48 Ocean and coastal ecosystems provide suitable habitats to a high number of species that support important 49 local fisheries, the tourism sector and the economy of the region (high confidence) (Section 3.5; Table 3.9; 50 González and Holtmann-Ahumada, 2017; Venerus and Cedrola, 2017; CEPAL, 2018; Carvache-Franco et 51 al., 2019; SROCC Section 5.4 Bindoff et al., 2019). There is high confidence that CSA ocean and coastal 52 ecosystems are already impacted by climate change (Figure 12.9, 12.10; Table SM12.3; Section 3.4; , 53 Section 5.4 in SROCC, Bindoff et al., 2019), and highly sensitive to non-climate stressors (Figure 12.8; 54 Table SM12.3; Section 3.4). Projections for CSA ocean and coastal ecosystems alert about significant and 55 negative impacts (high confidence) which include major loss of ecosystem structure and functionality, 56 changes in the distributional range of several species and ecosystems, major mortality rates, and increasing ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 12 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 12-54 Total pages: 181 1 number of coral bleaching events (Figure 12.9; Figure 12.10; Table SM12.3; Section 3.4; SROCC Sections 2 5.3, 5.4, Bindoff et al., 2019). | Heritage | 2231 - 2232 |
| IPCC | IPCC_AR6_WGII_Full_Report | 3 4 12.5.2.2 Adaptation success in ocean and coastal ecosystems of CSA 5 6 There is low evidence about how the strategies and actions taken and implemented in ocean and coastal 7 systems of CSA have contributed to advance in the protection and conservation of ocean and coastal 8 ecosystems. However, some important advances are visible in Colombian Pacific areas with coral reefs (new 9 conservation plans, research monitoring and conservation practices) (low confidence) (Cruz-Garcia and 10 Peters, 2015; Alvarado et al., 2017; Bayraktarov et al., 2020). In Panama, actions taken have allowed the 11 protection of a high number of marine areas with coral reefs, as well as the incorporation of management 12 approaches that include several sectors such as fisheries, tourism, coral protection and coral conservation 13 (low confidence) (Alvarado et al., 2017). In the case of Costa Rica, 80% of coral habitats are located inside 14 of MPAs, multiple research coral-related activities have been performed, and several training activities have 15 favoured the engagement of the local community in their protection against climate and non-climate hazards 16 (low confidence) (Alvarado et al., 2017). | Heritage | 2233 - 2233 |
| IPCC | IPCC_AR6_WGII_Full_Report | 17 18 There is low evidence of how the incorporation of mangroves as Ramsar sites, the reforms of legislations 19 (e.g., fines and stronger regulations), and the creation of reserves and private protection initiatives (e.g., 20 Belize Association of Private Protected Areas BAPPA), and capacity-building projects or new educational 21 programs have promoted the protection of mangroves in CSA countries such as Honduras, Guatemala and 22 Belize (Cvitanovic et al., 2014; Carter et al., 2015; Ellison et al., 2020). In Brazil, between 75–84% of 23 mangroves are under some level of protection which has improved the forest structures, and multiple 24 research programs (e.g., Mangrove Dynamics and Management, MADAM, and ‘GEF-Mangle’) have been 25 developed (medium confidence) (Krause, 2014; Medeiros et al., 2014; Estrada et al., 2015; Ferreira and 26 Lacerda, 2016; Oliveira-Filho et al., 2016; Borges et al., 2017; Maretti et al., 2019; Strassburg et al., 2019). | Heritage | 2233 - 2233 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 12 13 Some important limits and barriers have been detected for productive systems such as fisheries and tourism 14 in CSA (medium confidence: medium evidence, high agreement). Brazilian major fisheries management do 15 not follow an ecosystem approach, although some small-scale fisheries apply a precautionary approach 16 (Singh-Renton and McIvor, 2015). The management of Peruvian artisanal (medium and small-scale 17 fisheries) are minimal with an important lack of regulations, control, and management actions (Bertrand et 18 al., 2018). In Argentina, marine recreational fisheries have been largely unregulated with a lack of 19 monitoring programs which have contributed to the overexploitation of some key coastal stocks (Venerus 20 and Cedrola, 2017). Moreover, the participation of women fishers in CSA is not equally considered being 21 excluded from the decision-making processes (FAO, 2016b; Bruguere and Williams, 2017). Due to the lack 22 of monitoring programs, it is unknown how this tourism industry will respond to long-term changes driven 23 by climate change (Weatherdon et al., 2016). | Heritage | 2236 - 2236 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 8 9 12.5.3.2 Main concepts and approaches 10 11 Adaptation in the water sector includes a broad set of responses to improve and transform, among others, 12 water infrastructure, ecosystem functions, institutions, capacity building and knowledge production, habits 13 and culture, and local-national policies (Section 4.6). | Heritage | 2238 - 2238 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 14 15 Most adaptive water management approaches in CSA centre around extending the water supply side 16 including large infrastructure projects. However, 'hard path' interventions are now strongly contested due to 17 negative effects exacerbating local water conflicts (Carey et al., 2012; Boelens et al., 2019; Drenkhan et al., 18 2019), potentially leading to increasing water demand, vulnerabilities and water shortage risks (Di 19 Baldassarre et al., 2018), and, hence, limiting adaptive capacity (high confidence) (Ochoa-Tocachi et al., 20 2019). More integrated approaches focus on multi-use of water storage with shared stakeholder vision, 21 responsibilities, rights and costs, as well as risks and benefits, and often integrating water and risk 22 management (Branche, 2017; Haeberli et al., 2017; Drenkhan et al., 2019). In this chapter, a feasibility 23 assessment was carried out for six major dimensions of multi-use water storage for the entire CSA (see Table 24 12.11). While geophysical and economic aspects allow for the implementation of water storage projects with 25 multi-use approach, the institutional, social and environmental dimensions pose a major barrier (see Section 26 12.5.3). Further demand-oriented approaches focus on incentives for the reduction of water use through 27 changes in people's habits, efficiency increase and smart water management (Gleick, 2002). These are 28 promoted in some regions, such as in CA and NWS (e.g., Colombia, Ecuador and Peru), to foster a 29 sustainable water culture (Bremer et al., 2016; Paerregaard et al., 2016). | Heritage | 2238 - 2238 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 3 4 Most barriers to advance adaptation in CSA correspond to soft limits associated with missing links of 5 science-society-policy processes, institutional fragilities, pronounced hierarchies, unequal power relations 6 and top-down water governance regimes (high confidence). One example is the abandonment of hydrological 7 long-term monitoring sites within tropical Andean ecosystems (paramo) in Venezuela (Rodríguez-Morales et 8 al., 2019) due to the lack of governmental support within a political crisis. In that regard, the collection and 9 availability of consistent hydroclimatic and socioeconomic data at adequate scales represent an important 10 challenge in CSA. Major adaptation barriers are furthermore reported from Central Chile in the context of a 11 mega-drought since 2010, related to socioeconomic characteristics and a deficient bottom-up approach to 12 public policy informing and development (Aldunce et al., 2017). These gaps could be bridged by 13 strengthening transdisciplinary approaches at the science-policy interface (Lillo-Ortega et al., 2019) with 14 blended bottom-up and top-down adaptation to include scientific knowledge with impact and scenario 15 assessments into local adaptation agendas (Huggel et al., 2015b). For instance, a new allocation rule for the 16 Laja reservoir in Southern Chile (SWS), based on consistent water balance modelling results, could inform 17 policy and water management and potentially improve local water management and reduce water conflicts 18 on the long term (Muñoz et al., 2019b). | Heritage | 2241 - 2241 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 47 48 Limited information regarding cost-benefit analyses of adaptation is available in the region as well as 49 avoiding maladaptation effects and promoting site-specific and dynamic adaptation options considering 50 available technologies (medium confidence) (Roco et al., 2017; Zavaleta et al., 2018; Ponce, 2020; Shapiro- 51 Garza et al., 2020). | Heritage | 2242 - 2242 |
| IPCC | IPCC_AR6_WGII_Full_ Report | Coffee, beans and maize Several adaptation practices Awareness of climate change Affordabilit y of adaptation practices Lack of adaptatio n involving agroecolo gical and socioeco nomic contexts Chen et al. (2018) Costa Rica and Nicaragua 559 Quant. Several crops Intensificatio n and diversificatio n Access to weather information Participation in organization s Credit access Farming experience Land renting Lack of crop and practices diversific ation Vidal Merino et al. (2019) Peru 137 Quant. Several crops Water management Farm size Capital Irrigated proportion Limited access to off-farm activities Small cultivated area Lack of site�specific design of interventi ons Meldrum et al. | Heritage | 2245 - 2245 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 5 6 Housing programs and initiatives that consider resilient construction, and site selection strategies, are still in 7 nascent stages (Martin et al., 2013). Initiatives in slum upgrading, social housing improvement and 8 regularizing land tenure, associated with infrastructure provision, do not usually focus on adaptation, 9 although they often focus on risk reduction. Those initiatives, associated with a housing policy that 10 guarantees access to land and decent housing, a comprehensive intervention in vulnerable neighbourhoods 11 for their adaptation to climate change, and CbA (community-based adaptation) strategies, including housing 12 self-management and the participation of cooperatives, shows the need and opportunity to move to an 13 transformative urban agenda that encompasses sustainable development, poverty reduction, disaster-risk 14 reduction, climate-change adaptation, and climate-change mitigation (high confidence) (Muntó, 2018; UN- 15 Habitat, 2018; Valadares and Cunha, 2018; Bárcena et al., 2020b; Núñez Collado and Wang, 2020; 16 Satterthwaite et al., 2020). | Heritage | 2249 - 2249 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 17 18 Another example of a public adaptation measure is protection and restoration of natural areas, which have 19 the potential to decrease the transmission of water- and vector-borne infectious diseases (medium 20 confidence: robust evidence, low agreement). Studies have shown that these measures can diminish the cases 21 of malaria and diarrhoea in Brazil, and cases of diarrhoea in children in Colombia (Bauch et al., 2015; 22 Herrera et al., 2017; Chaves et al., 2018). However, deforestation and malaria have a complex relationship 23 that relies on local context interactions, where land use and land cover change present an important role due 24 to vector ecology alterations and social conditions of human settlements (Rubio-Palis et al., 2013). Forest 25 conservation can improve hydrological cycle control and soil erosion that can help to improve water quality 26 and reduce the burden of water-borne diseases. In addition, forest cover can help to diminish the habitat for 27 larval mosquitoes that transmit malaria. These measures can help to design policies in sites where these ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 12 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 12-77 Total pages: 181 1 problems do not currently exist but can emerge as a consequence of climate change and the increase in the 2 frequency of weather extreme events. | Heritage | 2254 - 2255 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 35 36 In IPCC's TAR, AR4 and AR5, WG II recognized higher risks associated with poor living conditions, 37 substandard housing, inadequate services, location in hazardous sites due to no alternatives and the need to 38 work more strongly on strengthening governance structures involving residents, community organizations 39 amongst others (Wilbanks et al., 2007; Revi et al., 2014). The AR5 CSA chapter stated that poverty levels 40 remained high (45% for CA and 30% for SA in 2010) despite years of sustained economic growth. Poor and 41 vulnerable groups are disproportionately affected in negative ways by climate change (Section 8.2.1.4; 42 Section 8.2.2.3; SR15 Section 5.2 and Section 5.2.1, Roy et al., 2018) ) due to physical exposure derived 43 from the place where they live or work, illiteracy, low income and skills, political and institutional 44 marginalization tied to lack of recognition of informal settlements and employments, poor access to good 45 quality services and infrastructure, resources, information, and other factors (very high confidence) (UN- 46 Habitat, 2018; SR15 Sections 5.2.1, 5.6.2, 5.6.3, 5.6.4, Roy et al., 2018). | Heritage | 2256 - 2256 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 37 38 There is also increasing evidence of human mobility associated with climate change and disaster risk (IOM, 39 2021) and the adoption of sustainable tourism, diversification of livelihoods strategies, climate forecasts, 40 appropriate construction techniques, neighbourhood layout, integral urban upgrading initiatives, territorial 41 and urban planning, regulatory frameworks, water harvesting and nature-based solutions (NbS) (Stein and 42 Moser, 2014; Hardoy and Mastrangelo, 2016; Almeida et al., 2018; Barbier and Hochard, 2018a; Desmaison 43 et al., 2018; Satterthwaite et al., 2018; Villafuerte et al., 2018; Hidalgo, 2020; Satterthwaite et al., 2020). | Heritage | 2259 - 2259 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 34 Indigenous and social movements have joined with climate justice activists, claiming for action against 35 climate change (Hicks and Fabricant, 2016; Ruiz-Mallén et al., 2017; Charles, 2021). The Bolivian Platform 36 against Climate Change, a coalition of civil society and social movement organizations working to address 37 the effects of global warming in Bolivia and to influence the broader global community, reflects an 38 innovative dimension that, albeit at time conflictual, has flagged how increasing climate variability hinders 39 the right of Indigenous Peoples to the conservation of their culture and practices and illustrates how grass- 40 root movements are increasingly appropriating climate change policy in the region (Hicks and Fabricant, 41 2016). Social movements have engaged with international networks as Blokadia, which surged after COP 23, 42 whose vindications try to go beyond the protection of the environment, delving into issues of democracy and 43 resource control (Martínez-Alier et al., 2018). | Heritage | 2261 - 2261 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 10 11 Mean air temperature and annual rainfall (measured through instruments since 1891 and inferred through 12 historical records of rogation ceremonies since 1600), are increasing, combined with an increase in 13 seasonality (i.e., longer periods of drought) and extreme weather events, particularly stronger precipitations 14 (Serrano Vincenti et al., 2017; Domínguez-Castro et al., 2018). Two impacts related to warmer air conditions 15 are the displacement of the freezing line currently placed at 5100 m.a.s.l. (Basantes-Serrano et al., 2016), 16 followed by glacier retreat and the upward displacement of mountainous ecosystems (very high confidence) 17 (Vuille et al., 2018; Cuesta et al., 2019). The key ecosystem that regulates water provision for the city is the 18 paramo, and only about 5% of this process is related with glaciers, so the combined effects of climate change 19 on both systems, coupled with land use change and fires, can reduce the availability of water for agriculture, 20 human consumption and hydropower. Other important climatic hazards and impacts are the increase of solar 21 radiation, the heat island effect and fires (high confidence) (Anderson et al., 2011; Armenteras et al., 2020; 22 Ranasinghe et al., 2021). Almost half of the days of each year, Quito's population is exposed to levels of UV 23 radiation above 11 according to the World Health Organization scale (Municipio del Distrito Metropolitano 24 de Quito, 2016). | Heritage | 2272 - 2272 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 25 26 Various policies, programs and projects have been created for the promotion of urban green spaces, 27 protected areas, water sources and watersheds monitoring, conservation and ecosystem restoration, air 28 pollution monitoring and control, and urban agriculture. Among those actions, three recent are commonly 29 highlighted. The first is the Fund for the Protection of Water (FONAG), established in 2000 with funds of 30 national and international organizations, to promote the protection of the water basins that supply most of the 31 drinking water. It is a PES-Scheme (Payment for Ecosystem Services) enabled through a public-private 32 escrow. The projects include conservation, ecological restoration, and environmental education for a new 33 culture of water, in a context opposed to the commodification of natural resources (Kauffman, 2014; Bremer 34 et al., 2016; Coronel T, 2019). FONAG was innovative in the use of trust funds in a voluntary, decentralized 35 mechanism and has inspired more than 21 other water funds in the region; nevertheless, its narrative of 36 success has also been said to over-simplify and misrepresent some complex interactions between 37 stakeholders as well as within communities and their land management practices (Joslin, 2019). | Heritage | 2272 - 2272 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 19 20 The institutionalized culture of participation in Peru did lead to a broader concept of concertation, wherein 21 practices of collaborative planning were developed to allow actors to build up socially supported agreements, 22 decisions and take actions without losing sight of their principles. These processes have been applied to 23 reduce risks, to adapt and to anticipate uncertain and unknown futures; and introducing climate change 24 concerns within a complex political and institutional environment surrounded by corruption scandals 25 (Vergara, 2018; Durand, 2019) and growing political polarization. | Heritage | 2275 - 2275 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 19 20 12.7.1 Knowledge Gaps in the Subregions 21 22 The knowledge gaps in the eight subregions are quite heterogeneous. In CA, climate change research is 23 notably insufficient in all sectors included in this report, considering that climatic change, variability, and 24 extremes are and will severely impact this subregion, and the vulnerability of the social and natural systems 25 is high. Data deficiencies must be overcome as renewed research on climate change updates models, 26 scenarios, and projected impacts across sectors and levels (i.e., household to country). In NWS, there is a 27 lack of studies on the relationships with increased fire events, and the impacts on the infrastructure of all 28 kinds, on certain lowland, marine and coastal ecosystems, and on ecosystem functioning and the provision of 29 environmental services. Experimental studies are rare, most necessary to identify critical ecological 30 thresholds to support the decision-making processes, linking glacier retreat to its consequences on 31 biodiversity and ecosystems, combined with different land-use trajectories. Complex interactions with 32 processes such as peace agreements in Colombia are yet to be studied (Salazar et al., 2018). In NSA, there is 33 still a limited amount of peer-reviewed literature, addressing the implications of climate change on 34 Indigenous cultures and their livelihoods. In SAM, further data are needed on the vulnerability of traditional 35 populations, impacts on water availability and soil degradation, risks to biodiversity and resilience of 36 ecosystems, attributed to climate change. | Heritage | 2277 - 2277 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 40 41 12.7.2.4 Food, Fibre and other Ecosystem Products 42 43 Integrative evaluation on impacts on food security, including agricultural production, distribution and access, 44 leading to adaptation strategies is limited within the region. Limited information regarding cost-benefit 45 analyses of adaptation in the food production sector is available in the region. It is also important to advance 46 in a better understanding of the adaptation effects to avoid maladaptation and promote site-specific and 47 dynamic adaptation options considering available technologies. Compiling and systematizing existing 48 scientific and local knowledge on the relationship between forest, land cover/use, and hydrological services, 49 is a gap to be filled, in a broader perspective in the region, that can contribute to provide recommendations 50 and inform restoration practices and policies. The literature also highlights widespread gaps between 51 farmers' information needs and services that are routinely available. There is evidence that when Climate 52 Information Services are constructed with farmer input and are targeted in a timely and inclusive manner, 53 they are a positive determinant of adaptation through the adoption of more resilient farm level practices. | Heritage | 2278 - 2278 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 32 33 12.7.2.8 Cross Cutting Issues it the Human Dimension 34 35 There is a significant number of studies addressing the impacts of climate change on the Amazon forest 36 (Brienen et al., 2015; Doughty et al., 2015; Feldpausch et al., 2016; Rammig, 2020; Sullivan et al., 2020); 37 however, the assessment of tangible and intangible impacts of climate change on Indigenous Peoples 38 cultures and livelihoods in this forest, need to be further advanced (Brondízio et al., 2016; Hoegh-Guldberg 39 et al., 2018). | Heritage | 2280 - 2280 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 15 16 17 12.8 Conclusion 18 19 Central and South America (CSA) is a broadly heterogeneous region in its topography, ecosystems, urban 20 and rural territories, demography, economy, cultures and climates. The region relies on a strong agrarian 21 economy in which small producers and large industries participate, but also large industrialized urban 22 centres, oil production and mining. The region is one of the most urbanized of the world and home to many 23 Indigenous Peoples, some still in isolation, and exhibits one of the highest rates of inequality, which is a 24 structural and growing characteristic in CSA. Poverty and extreme poverty rates are higher among children, 25 young people, women, Indigenous Peoples, migrant and rural populations but urban extreme poverty is also 26 growing (very high confidence). Socioeconomic challenges are intensified by COVID crisis. Most countries 27 in CA are already ranked as the highest risk level worldwide due to its exposure combined to high 28 vulnerability and low adaptive capacity; the lack of climate data and proper downscaling are challenging the 29 adaptation process (high confidence). | Heritage | 2281 - 2281 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 4 5 Many impacts in the economy are expected from climate change. Subsistence farmers and urban poor are 6 expected to be the most impacted by droughts and variable rainfall in the region (high confidence). The 7 increasing water scarcity is and will continue to impact food security, human health and well-being. The 8 impacts of the many landslides and floods affect mainly the urban poor neighbourhoods and are responsible 9 for the majority of the deaths related to natural disasters. Sea-level rise and intense storm surges are expected 10 to impact the tourism and industry in general. Internal and international migrations and displacements are 11 expected to increase (high confidence). Climatic drivers such as droughts, tropical storms and hurricanes, 12 heavy rains and floods, interact with social, political, geopolitical and economical drivers (high confidence). | Heritage | 2282 - 2282 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 43 This process degraded the ability of coastal ecosystems, such as mangroves, to reduce risks and provide 44 essential ecosystem services which help to prevent coastal erosion or maintain fish stocks. Moreover, it 45 reduced ports, tourism, along with income opportunities. | Heritage | 2285 - 2285 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 29 Glacier retreat and water scarcity are becoming strong drivers of migration in the Andes. Sea level rise 30 influences activities such as fishing and tourism, which will foster further migration. In Brazil, at least 0.9 31 million more people will migrate inter–regionally under future climate conditions. | Heritage | 2287 - 2287 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 34 35 The wide range of adaptation practices based on Indigenous knowledge in the region include, among others: 36 increasing species and genetic diversity in agricultural systems through community seed exchanges; 37 promotion of highly diverse crop systems; ancient systems to collect and conserve water; fire prevention 38 strategies; observing and monitoring changes in communal ecological–agricultural calendar cycles; 39 recognizing changes in ecological indicators like migration patterns in birds, behaviour of insects and other 40 invertebrates and phenology of fruit and flowering species; and systematization and knowledge exchange 41 among communities. These practices represent a valuable cultural and biological heritage. | Heritage | 2289 - 2289 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 49 50 Traditional fire management among Indigenous Peoples of Venezuela, Brazil and Guyana is another 51 adaptation strategy based on a fine–tuned understanding of environmental indicators, associated with their 52 culture and worldviews. In these countries, Indigenous lands have the lowest incidence of wildfires, 53 significantly contributing to maintaining and enhancing biodiversity. These traditional practices have helped 54 to prevent large–scale and destructive wildfires, reducing the risk from rising temperature and dryness due to 55 climate change. | Heritage | 2289 - 2289 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 35 36 KR4: Due to warming, changes in precipitation and sea level rise, risks to people and infrastructures 37 from coastal, riverine, and pluvial flooding will increase in Europe (high confidence). Risks of 38 inundation and extreme flooding will increase with accelerating pace of sea level rise along Europe's coasts 39 (high confidence). Above 3°C GWL, damage costs and people affected by precipitation and river flooding may double. Coastal flood damage is projected to increase at least 10-fold by the end of the 21st 40 century, and 41 even more or earlier with current adaptation and mitigation (high confidence). Sea level rise represents an 42 existential threat for coastal communities and their cultural heritage, particularly beyond 2100 43 {13.2.1;13.2.2;13.6.2;13.10.2.4;Box 13.1; Cross-Chapter Box SLR in Chapter 3). | Heritage | 2363 - 2363 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 49 50 Systemic barriers constrain the implementation of adaptation options in vulnerable sectors, regions 51 and societal groups (high confidence). Key barriers are limited resources, lack of private sector and citizens 52 engagement, insufficient mobilisation of finance, lack of political leadership, and low sense of urgency. Most 53 of the adaptation options to the key risks depend on limited water and land resources, creating competition 54 and trade-offs, also with mitigation options and socio-economic developments (high confidence). Europe 55 will face difficult decisions balancing these trade-offs. Novel adaptation options are pilot tested across 56 Europe, but upscaling remains challenging. Prioritisation of options and transitions from incremental to ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 13 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 13-6 Total pages: 143 1 transformational adaptation are limited due to vested interests, economic lock-ins, institutional path- 2 dependencies, and prevalent practices, cultures, norms, and belief systems {13.11.1;13.11.2;13.11.3}. | Heritage | 2364 - 2365 |

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| Organisation | Document | Quotation Content | Codes | Page |
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| IPCC | IPCC_AR6_WGII_Full_ Report | 36 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 13 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 13-9 Total pages: 143 1 2 13.1.3 Impact Assessment of Climate Change based on Previous Reports 3 4 The main findings of previous reports, particularly the WGII AR5 (Kovats et al., 2014) and the Special 5 Report of Global warming of 1.5°C GWL (Hoegh-Guldberg et al., 2018), highlighted the impacts of 6 warming and rainfall variations and their extremes on Europe, particularly southern Europe and mountainous 7 areas. At 2°C GWL, 9% of Europe's population was projected to be exposed to aggravated water scarcity, 8 and 8% of the territory of Europe were characterized to have a high or very high sensitivity to desertification 9 (UNEP/UNECE, 2016). These impacts are driven by changes in temperature, precipitation, irrigation 10 developments, population growth, agricultural policies, and markets (EEA, 2017a). Heat is a main hazard for 11 high-latitude ecosystems (Kovats et al., 2014; Jacob et al., 2018; Hock et al., 2019). The majority of 12 mountain glaciers lost mass during the last two decades, and permafrost in the European Alps and 13 Scandinavia is reducing (Hock et al., 2019). In central Europe, Scandinavia and Caucasus, mountain glaciers 14 were projected to lose 60% to 80% of their mass by the end of the 21st century (Hock et al., 2019). The 15 combined impacts on tourism, agriculture, forestry, energy, health and infrastructure were suggested to make 16 southern Europe highly vulnerable and increase the risks of failures and vulnerability for urban areas (Kovats 17 et al., 2014). Previous reports stated that the adaptive capacity in Europe is high compared to other regions of 18 the world, but that there are also limits to adaptation from physical, social, economic, and technological 19 factors. Evidence suggested that staying within 1.5°C GWL would strongly increase Europe's ability to 20 adapt to climate change (de Conick and Revi, 2018). | Heritage | 2367 - 2368 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 12 13 14 13.2 Water 15 16 13.2.1 Observed Impacts and Projected Risks 17 18 13.2.1.1 Risk of Coastal Flooding and Erosion 19 20 Almost 50 million European citizens live within 10 m above mean sea level (Vousdoukas et al., 2020; 21 McEvoy et al., 2021). Without further adaptation (section 13.2.2), flood risks along Europe's low-lying 22 coasts and estuaries will increase due to sea level rise (SLR) compounded by storm surges, rainfall and river 23 runoff (high confidence) (Mokrech et al., 2015; Arns et al., 2017; Sayol and Marcos, 2018; Vousdoukas et 24 al., 2018a; Bevacqua et al., 2019; Couasnon et al., 2020). The population at risk of a 100-year flood event 25 starts to rapidly increases beyond 2040 (Vousdoukas et al., 2018a) reaching 10 million people under RCP8.5 26 by 2100 but stays just below the 10 million under RCP2.6 by 2150 (Figure 13.5, Haasnoot et al., 2021b) 27 assuming present population and protection. The number of people at risk is projected to increase and risk to 28 materialise earlier particularly under SSP5 due to increasing population trends(Vousdoukas et al., 2018a; 29 Haasnoot et al., 2021b). Under high rates of SLR resulting from rapid ice-sheet loss from Antarctica, risks 30 may increase by a third by 2150 (Haasnoot et al., 2021b). Expected annual (direct) damages due to coastal 31 flooding are projected to rise from €1.3 billion today to €13–39 billion by 2050 between 2°C and 2.5°C 32 GWL and €93–960 billion by 2100 between 2.5° and 4.4°C GWL, largely depending on socio-economic 33 developments (Cross-Chapter Box SLR in Chapter 3, Vousdoukas et al., 2018a) (high confidence in the sign; 34 low confidence in the numbers). UNESCO World Heritage sites in the coastal zone are at risk due to SLR, 35 coastal erosion and flooding (CCP4, Section 13.8.1.3, Marzeion and Levermann, 2014; Reimann et al., 36 2018b) as are coastal landfills and other key infrastructure in Europe (AR6/SROCC, Brand et al., 2018; 37 Beaven et al., 2020). | Heritage | 2371 - 2371 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 47 48 49 [START BOX 13.1 HERE] 50 51 Box 13.1: Venice and its Lagoon 52 53 Venice and its lagoon are a UNESCO World Heritage Site. This socio-ecological system is the result of 54 millennia of interactions between people and the natural environment. It is exposed to climatic and non- 55 climatic hazards: more frequent floods, warming, pollution, invasive species, reduction of salt marshes, 56 hydrodynamic and bathymetric changes, and waves generated by cruise ships and boat traffic. | Heritage | 2371 - 2371 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 9 Construction of the flood protection system started in 2003 and were used for the first time in October 2020 10 to protect the city from floods (Lionello et al., 2021b). This system of mobile barriers (MoSE) closes the 11 lagoon inlets to avoid floods when needed, while under normal conditions they lay on the seabed, thus 12 allowing ship traffic and the exchange between the lagoon and the sea (Molinaroli et al., 2019). To prevent 13 the flooding of the central monument area, additional measures are proposed including inlets, expansion of 14 saltmarshes, and pumping seawater into deep brackish aquifers to raise the city's level (Umgiesser, 1999; 15 Umgiesser, 2004; Teatini et al., 2011). | Heritage | 2372 - 2372 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 15 Peatlands in NEU and EEU and other historically important cultural landscapes in Europe are overexploited 16 for forestry, agriculture, and peat mining (Page and Baird, 2016; Tanneberger et al., 2017; Ojanen and 17 Minkkinen, 2020). Inland wetland RAMSAR convention sites in Europe, which constitute 47% of the global 18 sites, have lost area in WCE and gained in SEU from 1980 to 2014 (Xi et al., 2021). Forests in WCE were 19 impacted by the extreme heat and drought event of 2018, with effects lasting into 2019 (Schuldt et al., 2020) 20 and losses in conifer timber sales in Europe (Hlásny et al., 2021). | Heritage | 2380 - 2380 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 16 17 18 Disruption of habitat connectivity reduces resilience and is projected to impact 30% of lake and river 19 catchments in Europe by 2030, through drought and reduced river flows (Markovic et al., 2017) (medium 20 evidence). Average wetland area is not projected to change at 1.7°C GWL across Europe, while for > 4°C 21 GWL expanding sites in NEU are not sufficient to balance losses in SEU and WCE (high confidence) (Xi et 22 al., 2021). At 3°C GWL the alpine tundra habitat and its associated species are projected to be lost in the 23 Pyrenees and shrink dramatically in NEU, WCE and EEU (Anisimov et al., 2017; Barredo et al., 2020). | Heritage | 2382 - 2382 |

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| IPCC | IPCC_AR6_WGII_Full_Report | 30 31 13.3.2 Solution Space and Adaptation Options 32 33 Autonomous species adaptation, via range shifts towards higher latitudes and altitudes and changes in 34 phenology, but extirpation have been documented in all European regions (Figure 13.8) (very high 35 confidence). Lowering vulnerability by reducing other anthropogenic impacts (Gillingham et al., 2015), such 36 as land use change, habitat fragmentation (Eigenbrod et al., 2015; Oliver et al., 2017; Wessely et al., 2017), 37 pollution, and deforestation (Chapter 2), enhances adaptation capacity and biodiversity conservation (high 38 confidence) (Ockendon et al., 2018). Protected areas, such as the EU Natura 2000 network, have contributed 39 to biodiversity protection (medium confidence) (Gaüzère et al., 2016; Sanderson et al., 2016; Santini et al., 40 2016; Hermoso et al., 2018) but 60% of terrestrial species in these sites could lose suitable climate niches at 41 4°C GWL (Figure Box 13.1.1, EEA, 2017a). | Heritage | 2385 - 2385 |
| IPCC | IPCC_AR6_WGII_Full_Report | 27 28 The solution space for responding to climate-change risks for terrestrial ecosystem has increased in parts of 29 Europe (medium confidence). For example, EbA and NbS figure prominently in the EU Adaptation Strategy 30 (2021a) and climate change adaptation is mainstreamed in the EU Biodiversity Strategy for 2030 (European 31 Comission, 2020), the EU Forest Strategy for 2030 (European Comission, 2021b), the EU Green 32 Infrastructure Strategy (European Comission, 2013a), as well as several national and regional policies. Yet, 33 in the northern parts of EEU and NEU (e.g. Greenland, Iceland, NW Russian Arctic), areas which are often 34 sites of pronounced biodiversity shifts and changes, solutions are lacking or slow in emergence, due to 35 remoteness, lack of resources and sparse populations (Canosa et al., 2020). In the EU, innovative financing 36 schemes such as the Natural Capital Financing Facility are being explored by the European Investment Bank 37 and the European Commission which supports projects delivering on biodiversity and climate adaptation 38 through tailored loans and investments. Multiple EU-level service platforms have been promoted to track 39 climate change impacts on land ecosystems and adaptation (e.g. Climate-Adapt, Copernicus Land and Fire 40 Monitoring Service, Forest Information System of Europe) (13.11.1). | Heritage | 2386 - 2386 |
| IPCC | IPCC_AR6_WGII_Full_Report | 44 45 'Green' adaptations, either 'Ecosystem based Adaptations' or 'Nature based Solutions, are part of adaptive 46 management strategies (European Comission, 2011) that facilitate coastal flood protection (Section 13.2.2; 47 Chapter 3; CCC SLR) and generate benefits beyond habitat creation (medium confidence), e.g., from avoided 48 expenditures for flood defence infrastructure and avoided loss of the built assets (Gedan et al., 2010). Marine 49 Protected Areas (MPAs) have been identified as adaptation options for natural areas, including permitted and 50 non-permitted uses (Chapter 3, Selig et al., 2014; Hopkins et al., 2016a; Roberts et al., 2017). The extent of 51 MPAs has been increasing in Europe, albeit with strong regional variations (Figure 13.12). MPAs provide 52 protection from local stressors, such as commercial exploitation, and enhance the resilience of marine and 53 coastal ecosystems and thus lessen the impacts of climate change (medium confidence) (Narayan et al., 2016; 54 Roberts et al., 2017). However, climate change risk reduction is only a limited MPA objective (Hopkins et 55 al., 2016b; Rilov et al., 2019). The implementation of the legal frameworks, such as the EC Habitats 56 Directive and EC Birds Directive, allows for enabling adaptation (Verschuuren, 2015) as does the 57 incorporation of climate considerations in management of Natura 2000 sites (European Comission, 2013b). | Heritage | 2390 - 2390 |
| IPCC | IPCC_AR6_WGII_Full_Report | 35 36 37 13.6 Cities, Settlements and Key Infrastructure 38 39 Urban areas in Europe offer home to 547 million inhabitants, corresponding to 74% of the total European 40 population (UN/DESA, 2018). In the EU-28, 39% of the total population lives in metropolitan regions (i.e., 41 areas with at least one million inhabitants) where 47% of the total GDP is generated (Eurostat, 2016). Apart 42 from urban settlements, this section also covers energy and transport systems, as well as tourism, industrial 43 and business sectors which are key for livelihood, economic prosperity and well-being of residents. | Heritage | 2400 - 2400 |
| IPCC | IPCC_AR6_WGII_Full_Report | 22 23 13.6.1.4 Tourism 24 25 Snow cover duration and snow depth in the Alps decreased since the 1960s (Klein et al., 2016; Schöner et 26 al., 2019; Matiu et al., 2021). Despite snowmaking, the number of skiers to French resorts at low elevations 27 during the extraordinary warm/dry winters of 2006/2007 and 2010/2011 was 12-26% lower (Falk and Vanat, 28 2016). | Heritage | 2403 - 2403 |
| IPCC | IPCC_AR6_WGII_Full_Report | 29 30 Due to reduced snow availability and hotter summers, damages are projected for the European tourism 31 industry, with larger losses in SEU (high confidence) and some smaller gains in the rest of Europe (medium 32 confidence) (Ciscar et al., 2014; Roson and Sartori, 2016; Dellink et al., 2019). | Heritage | 2403 - 2403 |
| IPCC | IPCC_AR6_WGII_Full_Report | 43 44 Climatic conditions from May to October at 1.5-2°C GWL are projected to become more favourable for 45 summer tourism in NEU and parts of WCE and EEU, while there is medium confidence on opposite trends 46 for SEU from June to August (Grillakis et al., 2016; Scott et al., 2016; Jacob et al., 2018; Koutroulis et al., 47 2018). The amenity of European beaches may decrease as a result of sea level rise amplifying coastal erosion 48 and inundation risks, although less in NEU (Ebert et al., 2016; Toimil et al., 2018; Lopez-Doriga et al., 2019) 49 (Section 13.2 and Ranasinghe et al., 2021 Section 12.4.5). | Heritage | 2403 - 2403 |
| IPCC | IPCC_AR6_WGII_Full_Report | 36 37 38 Table 13.1: Present status of planned and implemented adaptation in cities, energy sector, tourism sector, transport and 39 industry in Europe ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 13 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 13-48 Total pages: 143 General commitments / Adaptation Plans Implemented adaptation actions Cities ● Increasing number of cities acknowledging the critical role of adaptation in building resilience to climate change. | Heritage | 2406 - 2407 |
| IPCC | IPCC_AR6_WGII_Full_Report | Tourism ● Consideration of tourism in national adaptation strategies is limited, and national tourism strategies rarely mention adaptation. | Heritage | 2407 - 2407 |

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| IPCC | IPCC_AR6_WGII_Full_Report | ● Tourism operators do not consider longer term adaptation strategies to be relevant. | Heritage | 2407 - 2407 |
| IPCC | IPCC_AR6_WGII_Full_Report | ● Legally binding consideration of climate change when constructing new tourism units (e.g., the 2016 French Mountain Act). | Heritage | 2407 - 2407 |
| IPCC | IPCC_AR6_WGII_Full_Report | ● Some diversification of tourism products offered in Mediterranean coastal destinations. | Heritage | 2407 - 2407 |
| IPCC | IPCC_AR6_WGII_Full_Report | 39 Effectiveness & feasibility of main adaptation options to climate impacts & risk for cities, settlements & key infrastructure in Europe Impact types Adaptation options Effectiveness Economic Technological Institutional Socio-cultural Ecological Geophysical Evidence Agreement Interventions in the building shell M M L M L NL M M M Ventilation (natural/mechanical, incl. night) M M H M L NL M H M Air conditioning H L NL NL L NL M L M Shading M L H L M NL L M M Green roofs, green walls L M M L M M M M M Urban green spaces L L M L M M M L M Use of 'cool' paints & coatings L H M L M NL H M M Escape to nearby non-urban destinations NL NL NL NL M NL NL L H Improvements in cooling systems M L M M NL NL M H M Shifting production to less water�intensive plants M M M L NL NL NL L H Regulatory measures L M NL M NL NL NL L M Management measures M M M M NL L M M M Use of heat-resilient materials L H L M M NL NL L H Replace vulnerable infrastructure with resilient one L M NL NL NL NL NL L H Legend █ High = H █ Medium = M █ Low = L No/Limited Evidence = NL Feasibility Confidence Reduction of thermal comfort due to increasing temperatures & extreme heat Loss of critical services due to heatwaves & drought ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 13 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 13-51 Total pages: 143 1 2 3 Figure 13.21: Indicative adaptation limits in cities, settlements and key infrastructure in Europe (Table SM13.16). | Heritage | 2409 - 2410 |
| IPCC | IPCC_AR6_WGII_Full_Report | 53 54 There is limited knowledge on interactions created by synchronous adaptation in ski tourism supply and 55 demand, and models are not yet including individual snowmaking capacity and a higher time resolution 56 (Steiger et al., 2019). Furthermore, there is no European-wide assessment of coastal flooding risks on 57 tourism. | Heritage | 2411 - 2411 |
| IPCC | IPCC_AR6_WGII_Full_Report | 23 24 25 The effectiveness of most options in reducing climate induced health risks is determined by many co- 26 founding factors, including the extent of the risk, existing socio-political structure and culture, and other 27 adaptation options in place (high agreement, medium evidence). Successful examples include the 28 implementation of heat wave plans (Schifano et al., 2012; van Loenhout and Guha-Sapir, 2016; De'Donato et 29 al., 2018), improvements in health services, and infrastructure of homes (Vandentorren et al., 2006) (Section 30 13.10.2.1). A study of nine European cities, for example, showed lower numbers of heat-related deaths in 31 Southern European cities, and attributed this to the implementation of heat prevention plans, a greater level 32 of individual and household adaptation, and growing awareness of citizens about exposure to heat 33 (de'Donato et al., 2015). Long-term national prevention programs in Northern Europe have been shown to 34 reduce temperature-related suicide (Helama et al., 2013). Physical fitness of individuals may increase 35 resilience to extreme heat (Schuster et al., 2017). Combining multiple types of adaptation options into a 36 consistent policy portfolio may have an amplifying effect in reducing risks, particularly at higher GWL 37 (Lesnikowski et al., 2019) (medium confidence) (Chapter 7). | Heritage | 2417 - 2417 |
| IPCC | IPCC_AR6_WGII_Full_Report | 52 53 54 13.8 Vulnerable Livelihoods and Social Inequality 55 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 13 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 13-60 Total pages: 143 1 This section addresses social consequences of climate change for Europe, by looking into consequences for 2 poor households and minority groups; migration and displacement of people; livelihoods particularly 3 vulnerable to climate change (indigenous and traditional communities); and cultural heritage. | Heritage | 2418 - 2419 |
| IPCC | IPCC_AR6_WGII_Full_Report | 7 8 13.8.1.3 Loss and Damage to Vulnerable Livelihoods in Europe 9 10 A number of livelihoods maintaining unique cultures in Europe is particularly vulnerable to climate change 11 (Table 13.2): indigenous communities in the European polar region because of their dependence on 12 cryosphere ecosystems (high confidence) (CCP Polar, Hayashi, 2017; Huntington et al., 2017; Hock et al., 13 2019; Meredith et al., 2019; Inuit Circumpolar Council, 2020; Douville et al., 2021; Fox-Kemper et al., 14 2021) and communities dependent on small-scale fisheries, traditional farming and unique cultural 15 landscapes (medium confidence) (Kovats et al., 2014; Ruiz-Díaz et al., 2020). | Heritage | 2420 - 2420 |
| IPCC | IPCC_AR6_WGII_Full_Report | 16 17 For Sámi reindeer herding impacts cascade due to a lack of access to key ecosystems, lakes and rivers 18 thereby threatening traditional livelihoods, food security, cultural heritage (e.g. burial grounds, seasonal 19 dwellings and routes), mental health (Box 13.2 and Figure 13.13, Feodoroff, 2021), and growing costs for 20 example as a result of the need for artificial feeding of reindeer. | Heritage | 2420 - 2420 |
| IPCC | IPCC_AR6_WGII_Full_Report | Human life Communal and production sites and intrinsic value Sense of place Agency and identity Cultural artefacts Psychological and emotional distress Biodiversity and ecosystems 25 Climate hazard Change in exposure and vulnerability Observed impact / projected risk Loss of livelihood, culture, health and wellbeing of the Sámi and the Nenets. | Heritage | 2420 - 2420 |
| IPCC | IPCC_AR6_WGII_Full_Report | Loss of livelihood (e.g. reindeer herding), loss of food security (cold dependent species), culture, health (impact on safety; psychological impacts from stress to reindeer and Indigenous way of life), and cultural and linguistic wellbeing; release of anthrax from permafrost soils in the Nenets area. | Heritage | 2420 - 2420 |

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| IPCC | IPCC_AR6_WGII_Full_Report | Warmer winters lead to loss of income from ice fishing and cultural heritage in Finland. | Heritage | 2421 - 2421 |
| IPCC | IPCC_AR6_WGII_Full_Report | Abandonment of summer pastures and farms, with negative consequences for farming income, tourism, cultural and aesthetic values. | Heritage | 2421 - 2421 |
| IPCC | IPCC_AR6_WGII_Full_Report | Reduced yields on semi-natural grasslands, compromising livestock feeding in winter, and ultimately decreasing viability of pastoralism in the Spanish Pyrenees Higher temperatures and more variable precipitation, less snow, change in seasonality and drought Demographic change, change in policy and market conditions, simplification of pastoral practices and agroecosystems, land abandonment or afforestation of marginal pastoral lands and intensification of more favourable lands in the lowlands, troublesome coexistence with tourism and nature conservation initiatives Decreasing viability of pastoralism, concentration of pastoral production on most profitable locations for intensive rearing of livestock with abandonment of the rest of the land; pastoral land encroachment both by shrubs and other activities; grassland degradation; biodiversity loss Retreating glaciers and changes in the landscape lead to loss of identity, culture and self-reliance in the Italian Alps (Alto Adige) ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 13 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 13-63 Total pages: 143 1 2 3 [START BOX 13.2 HERE] 4 5 Box 13.2: Sámi Reindeer Herding in Sweden 6 7 Reindeer (Rangifer tarandus) are keystone species in northern landscapes (Vors and Boyce, 2009). Reindeer 8 herding is a traditional, semi-nomadic livelihood of the Sámi. Reindeer migrate between seasonal pastures 9 that cover 55% of Sweden and are simultaneously used for multiple other purposes (Sandström et al., 2016). | Heritage | 2421 - 2422 |
| IPCC | IPCC_AR6_WGII_Full_Report | 17 18 The documented and projected impacts on reindeer are complex and varied. Warming and CO2 increase 19 result in higher plant productivity (Section 13.3), changes in plant community composition, and higher 20 parasite harassment; unstable ice conditions affect migration; extreme weather conditions during critical 21 winter months, more frequent forest fires and changes in plant community composition reduce pasture 22 quality (medium confidence) (Mallory and Boyce, 2018) (Figure Box 13.2.1). High snow depth and rain-on�Glacier volume loss from increasing temperatures Vulnerability is mainly driven by reliance on tourism Loss of sense of community through shared memories, and history. Sadness caused by the loss of what feels like "home". Loss of well-being due to uncertainty and fear of the future. | Heritage | 2422 - 2422 |
| IPCC | IPCC_AR6_WGII_Full_Report | Critical importance of alpine natural forests and meadows for regulating services; Negative impacts of climate change are found mainly at low elevations and for specific species (Norway spruce); decrease in soil moisture due to abandonment of pastoralism result in reduced water provision for downstream water users Increase of sea temperature leads to shifts in distribution of cold water species, reducing productivity at lower latitudes. Artisanal fisheries in Southern European coastal areas (Mediterranean) that rely on local, nearshore stocks can have difficulties to adapt Increase in sea temperature Substitution of artisanal fisheries by industrial fisheries; less support by governments, shift in employment (e.g. tourism) which do not match the skill sets, education or desires of small-scale fishers; national quotas system leads to prices to high buy or lease quotas and immense amount of bureaucracy and regulations Due to their low investment capacity and boat size, fishers are limited in their movement to other fishing places when local fish stocks decline. Increasing sea temperatures are increasing the threat of invasive species in coastal ecosystems. | Heritage | 2422 - 2422 |
| IPCC | IPCC_AR6_WGII_Full_Report | 22 23 Maintaining and improving the solution space to adapt reindeer herding is crucial for reducing existing 24 impacts and projected risks of climate and land use change (Andersson et al., 2015; Turunen et al., 2016; 25 AMAP, 2017; Hausner et al., 2020). Lack of control over land use is the biggest and most urgent threat to the 26 adaptive capacity of reindeer herding and the right of Sámi to their culture (high confidence) (Pape and 27 Löffler, 2012; Andersson et al., 2015; Kløcker Larsen and Raitio, 2019). | Heritage | 2424 - 2424 |
| IPCC | IPCC_AR6_WGII_Full_Report | 28 29 [END BOX 13.2 HERE] 30 31 32 13.8.1.4 Cultural and Natural Heritage 33 34 Climate change poses a serious threat to preservation of cultural heritage in Europe, both tangible and 35 intangible (high confidence) (Haugen and Mattsson, 2011; Daire et al., 2012; Dupont and Van Eetvelde, 36 2013; Macalister, 2015; Phillips, 2015; Fatorić and Seekamp, 2017; Graham et al., 2017; Carroll and 37 Aarrevaara, 2018; Sesana et al., 2018; Iosub et al., 2019; Daly et al., 2020). At higher GWL, building 38 exteriors and valuable indoor collections become at risk (Leissner et al., 2015). Coastal heritage such along 39 the North Sea and Mediterranean are under water-related threats (Reimann et al., 2018b; Walsh, 2018; 40 Harkin et al., 2020) (Box 13.1 Venice; WGII AR6 CCP4). | Heritage | 2424 - 2424 |
| IPCC | IPCC_AR6_WGII_Full_Report | 41 42 Disappearing cultural heritage can reduce incomes due to loss of tourism (Hall et al., 2016), as exemplified 43 by glacier retreat e.g. in the Swiss Alps and Greenland (Bjorst and Ren, 2015; Bosson et al., 2019) 44 (CCP5.3.2.4). Glacier retreat can create a sense of discomfort, loss of sense of place, displacement and 45 anxiety in people (Section 13.7) (Albrecht et al., 2007; Brugger et al., 2013; Allison, 2015; Jurt et al., 2015). | Heritage | 2424 - 2424 |
| IPCC | IPCC_AR6_WGII_Full_Report | 46 Intangible cultural heritage, such as place names, and lost traditional practices can also be affected 47 (Mustonen, 2018; Dastgerdi et al., 2019). | Heritage | 2424 - 2424 |
| IPCC | IPCC_AR6_WGII_Full_Report | 15 16 European cultural heritage in general and world heritage sites specifically lack adaptation strategies to 17 preserve key cultural assets (Haugen and Mattsson, 2011; Howard, 2013; Heathcote et al., 2017; Reimann et 18 al., 2018b; Harkin et al., 2020). Key reasons are the underdeveloped adaptation actions available, resources 19 for implementing them, and absence of overarching policy guidance (Phillips, 2015; Fernandes et al., 2017; 20 Sesana et al., 2018; Daly et al., 2020) (Sesana et al., 2018; Fatorić and Biesbroek, 2020; Sesana et al., 2020). | Heritage | 2425 - 2425 |

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| IPCC | IPCC_AR6_WGII_Full_Report | 21 22 13.8.3 Knowledge Gaps 23 24 There is limited understanding of how different social groups are affected by the four European key risks 25 under future climate change (13.11.2), and by adaptation to them. Similarly, the interaction of multiple risks 26 across sectors and how this interaction results in displacement, migration, or immobility of people both 27 within and from outside Europe is insufficiently understood. For indigenous and traditional livelihoods in 28 Europe, the understanding of how risks will change at different warming levels is very limited, due to 29 complex interactions with socio-economic and political change. For European cultural heritage, there is also 30 a lack of tailored knowledge and understanding of the impacts and how to translate these into adaptation 31 measures. | Heritage | 2425 - 2425 |
| IPCC | IPCC_AR6_WGII_Full_Report | 6 7 8 13.10.2.4 KR4: Risks to people, economies and infrastructures due to coastal and inland flooding 9 10 Damages and losses from coastal and river floods are projected to increase substantially in Europe over the 11 21st century (high confidence) (Section 13.2.1, SM13.10). Coastal areas have already started to be affected 12 by sea level rise (Box13.1; Section 13.10.1) and human exposure to coastal hazards is projected to increase 13 in the next decades (high confidence), but less under SSP1 (20%) than SSP5 (50%) by the end of the century 14 (medium confidence) (Merkens et al., 2016; Reimann et al., 2018a). Under low adaptation (i.e. coastal 15 defences are maintained but not further strengthened), severe consequences include increase in expected 16 annual damage by a factor of at least 20 for 1.5-2.1°C GWL (i.e.. high risks) and by 2-3 orders of magnitude 17 between 2 and 3°C GWL in EU-28 (i.e. very high risk) (medium confidence) (Figure 13.28, 13.34c; Section 18 13.2.1.1); (Vousdoukas et al., 2018b; Haasnoot et al., 2021b). Under high adaptation (i.e. lowlands are 19 protected where it is economically efficient), expected annual damages still increase by a factor of 5 above 20 2°C GWL (Section13.2, Vousdoukas et al., 2020). Sea-levels are committed to rise for (Fox-Kemper et al., 21 2021), submerging at least 10% of the territory in 12 countries in Europe after millennia if GWL exceed 1.5- 22 2.5°C (Clark et al., 2016), and this represents a major threat for the European and Mediterranean cultural 23 heritage (Figure 13.28, Cross-Chapter Box SLR in Chapter 3, CCP4, Marzeion and Levermann, 2014; 24 Reimann et al., 2018b). | Heritage | 2434 - 2434 |
| IPCC | IPCC_AR6_WGII_Full_Report | 3 There is also some evidence of ‘short-sighted’ adaptation or maladaptation; for example, in winter tourism 4 there is a preference for technical and reactive solutions (e.g., artificial snow) that will not be sufficient under 5 high levels of warming (Section 13.6.1.4). | Heritage | 2442 - 2442 |
| IPCC | IPCC_AR6_WGII_Full_Report | 43 44 As warming and droughts impact southern Europe most strongly, direct opportunities from climate change 45 are primarily in northern regions, thereby increasing existing inequalities across Europe. Across Europe, 46 positive effects of climate change are fewer than negative impacts and are typically limited to some aspects 47 of agriculture, forestry, tourism, and energy sectors. In the food sector, opportunities emerge by the 48 northward movement of food production zones, increases in plant growth due to CO2 fertilisation, and 49 reduction of heating costs for livestock during cold winters. In the energy sector, positive effects include 50 increased wind energy in the southwestern Mediterranean, and reduced energy demand for heating across 51 Europe. While climatic conditions for tourist activities are projected to decrease for winter tourism (e.g. | Heritage | 2449 - 2449 |
| IPCC | IPCC_AR6_WGII_Full_Report | 52 lacking sufficient snow) and summer tourism in some parts of Europe (e.g. too hot), conditions may improve 53 during spring and autumn in many European locations. Fewer cold waves will reduce risks on transport 54 infrastructure, such as cracking of road surface, in parts of Northern and Eastern Europe particularly by the 55 end of the century. | Heritage | 2449 - 2449 |
| IPCC | IPCC_AR6_WGII_Full_Report | 14 Bellis, J., M. Longden, J. Styles and S. Dalrymple, 2021: Using macroecological species distribution models to estimate 15 changes in the suitability of sites for threatened species reintroduction. Ecological Solutions and Evidence, 2(1), 16 e12050, doi:https://doi.org/10.1002/2688-8319.12050. | Heritage | 2454 - 2454 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | FINAL DRAFT Chapter 14 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 14-4 Total pages: 157 1 Indigenous Peoples across North America (high confidence). Climate change has impacted aquaculture (high 2 confidence) and induced rapid redistribution of species (very high confidence), and population declines of 3 multiple key fisheries (high confidence). {14.5.4, 14.5.6, 14.7} 4 5 Climate change has impaired North American freshwater resources and reduced supply security (high 6 confidence). Reduced snowpack and earlier runoff (high confidence) have adversely affected aquatic 7 ecosystems and freshwater availability for human uses (medium confidence). Recent severe droughts, floods 8 and harmful algal and pathogen events have caused harm to large populations and key economic sectors 9 (high confidence). Heavy exploitation of limited water supplies, especially in the western US and northern 10 Mexico, and deteriorating freshwater management infrastructure, have heightened the risks (high 11 confidence). Effective examples of freshwater resource adaptation planning are already underway, but 12 coordinated adaptation implementation across multiple conflicting interests and users is complicated and 13 time consuming (high confidence). {14.5.1, 14.5.2, 14.5.3} 14 15 Extreme events and climate hazards are adversely affecting economic activities across North America 16 and have disrupted supply-chain infrastructure and trade (high confidence). Larger losses and 17 adaptation costs are observed for sectors with high climate exposures, including tourism, fisheries, and 18 agriculture (high confidence) and outdoor labor (medium confidence). Disaster planning and spending, 19 insurance, markets, and individual and household level adaptation have acted to moderate effects to 20 date (medium confidence). Entrenched socioeconomic vulnerabilities have amplified climate impacts for 21 marginalized groups, including Indigenous Peoples due to the impact of colonialism and discrimination 22 (medium confidence). {14.5.4, 14.5.5, 14.5.6, 14.5.7, 14.5.9, Box 14.1, Box 14.5, Box 14.6} 23 24 North American cities and settlements have been affected by increasing severity and frequency of 25 climate hazards and extreme events (high confidence), which has contributed to, infrastructure 26 damage, livelihood losses, damage to heritage resources, and safety concerns. Impacts are particularly 27 apparent for Indigenous Peoples for whom culture, identity, commerce, health and wellbeing are closely 28 connected to a resilient environment (very high confidence). Higher temperatures have been associated with 29 violent and property crime in the US (medium confidence) yet the overall effects of climate change on crime 30 and violence in North America are not well understood. {14.4, 14.5.5, 14.5.6, 14.5.8, 14.5.9, Box 14.1} 31 32 Terrestrial, marine, and freshwater ecosystems are being profoundly altered by climate change across 33 North America (very high confidence). Rising air, water, ocean and ground temperatures have restructured 34 ecosystems and contributed to the redistribution (very high confidence) and mortality (high confidence) of 35 fish, bird, and mammal species. Extreme heat and precipitation trends on land have increased vegetation 36 stress and mortality, reduced soil quality, and altered ecosystem processes including carbon and freshwater 37 cycling (very high confidence). Warm and dry conditions associated with climate change have led to tree die- 38 offs (high confidence) and increased prevalence of catastrophic wildfire (medium confidence) with an 39 increase in the size of severely burned areas in western North America (medium confidence). Nature-based 40 solutions and ecosystem-based management have been effective adaptation approaches in the past but are 41 increasingly exceeded by climate extremes (medium confidence). {14.5.1-3, Box 14.7} 42 43 Climate-driven changes are particularly pronounced within Arctic ecosystems and are unprecedented 44 based on observations from multiple knowledge systems (very high confidence). Climate change has 45 contributed to cascading environmental and socio-cultural impacts in the Arctic (high to very high 46 confidence) that have adversely, and often irreversibly, altered Northern livelihoods, cultural activities, 47 essential services, health, food and nutritional security, community connectivity, and wellbeing (high 48 confidence). {14.5.2, 14.5.4, 14.5.6, 14.5.7, 14.5.8, Box 14.6} 49 50 Future Risks and Adaptation 51 52 Climate hazards are projected to intensify further across North America (very high confidence). Heat 53 waves over land and in the ocean as well as wildfire activity will intensify; sub-Arctic snowpack, glacial 54 mass and sea ice will decline (virtually certain); and sea level rise will increase at geographically differential 55 rates (virtually certain). Humidity-enhanced heat stress, aridification, and extreme | Heritage | 2505 - 2509 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 8 9 10 14.3.3 Building Consensus on Climate Change 11 12 Building consensus for action on climate change is influenced by individual factors (e.g., ideology, 13 worldview, trust, partisan identity, religion, education, age) and the broader societal context (e.g., culture, 14 media coverage and content, political climate, economic conditions) (high confidence) (McCright and 15 Dunlap, 2011; Brulle et al., 2012; Hornsey et al., 2016; Arbuckle, 2017; Pearson et al., 2017; Bolsen and 16 Shapiro, 2018; Ballew et al., 2020; Cologna and Siegrist, 2020; Goldberg et al., 2020). In a multi-country 17 assessment of acceptance of global warming influenced by ideology (e.g., conspiratorial ideation, 18 individualism, hierarchy, and left–right and liberal–conservative political orientation), the US uniquely had 19 the strongest link to doubt out of 25 countries for all factors, while Canada's dominant influence on non- 20 acceptance was conservative political ideology, and for Mexico, there were no ideological effects (Hornsey 21 et al., 2018). | Heritage | 2518 - 2518 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 31 Interest in preserving local archaeological sites threatened by SLR initiated collaboration and co-production 32 of knowledge among disparate US communities -- citizens, archaeologists, preservationists, planners, land 33 managers, and Indigenous Peoples (Fatorić and Seekamp, 2019; Dawson et al., 2020). | Heritage | 2519 - 2519 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 52 53 54 [START BOX 14.1 HERE] 55 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 14 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 14-18 Total pages: 157 1 Box 14.1: Integrating Indigenous 'Responsibility-Based Thinking' into Climate Change Adaptation 2 and Mitigation Strategies 3 4 Indigenous Peoples throughout North America have experienced five centuries of territorial expropriation, 5 loss of access to natural resources and in many cases, barriers to the use of their sacred sites (Gabbert, 2004; 6 Louis, 2007). The history of Indigenous struggles to preserve distinct cultural knowledges and assert 7 autonomy in the face of colonialism has shaped land-use patterns and relationships with traditional territories 8 (Alfred and Corntassel, 2005; Tuhiwai Smith, 2021) (Cross-Chapter Box INDIG, Chapter 18). Climate 9 change is now creating additional challenges for Indigenous Peoples. For example, increased water scarcity 10 due to higher temperatures and diminished precipitation have led to reduced crop yields for Maya farmers in 11 the Yucatan (Sioui, 2019). Thawing permafrost in subarctic Canada (Quinton et al., 2019) has interfered with 12 the land-based livelihoods of the Indigenous Dene Peoples (CCP6). | Heritage | 2519 - 2520 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 41 42 Indigenous relationships with natural systems continue to be mediated by cultural orders of governance and 43 legal systems that pre-date, by several millennia, European traditions in North America. Napolean (2012) 44 describes Indigenous legal orders as dynamic and encompassing knowledge that is simultaneously legal, 45 religious, philosophical, social, and scientific. Customary Indigenous legal orders (e.g. Borrows, 2002; 46 Napolean, 2012) stand in contrast to Eurocentric understandings of law, which are closely related to, and 47 founded on, the Western principles of rights. Indigenous legal orders are based on duties, obligations and 48 responsibilities to the land and all beings, including humans, animals, plants, future generations and the 49 departed/ancestors (Borrows, 2002; Borrows, 2010a; Borrows, 2010b; Borrows, 2016). Indigenous spiritual 50 laws centred on the values of responsibility and accountability to the land, and how these differ, in theory 51 and in practice, from Western law, which is based on "universal" principles, with little consideration for the 52 local environmental context (Craft, 2014). Research has elucidated these Indigenous understandings about 53 how their land-based responsibilities act as the foundation of how humans must operate according to the land 54 on which they live and depend. | Heritage | 2520 - 2520 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 55 56 With increasing climate change threats to land-based subsistence and cultural practices, Indigenous Peoples 57 are increasingly taking their rightful leadership roles in resource co-management arrangements and other ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 14 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 14-19 Total pages: 157 1 stewardship activities (14.5.2.2). Indeed, Indigenous Peoples are increasingly assuming leadership positions 2 with regard to land governance and climate change action, as the stewards of their traditional territories since 3 time immemorial. Therefore, it is imperative for Indigenous scholars, Elders, and knowledge holders to 4 occupy leadership roles in climate change adaptation and mitigation, especially when their territories are 5 concerned (14.7; CCP6). For instance, Indigenous "resurgence" paradigms draw on the strengths of 6 traditional land-based culture and knowledge with regard to Indigenous leadership in land governance and 7 stewardship (Alfred and Corntassel, 2005; Alfred, 2009; Simpson, 2011; Corntassel and Bryce, 2012; 8 Coulthard, 2014; Alfred, 2015). Indigenous leadership in climate change policy, therefore, can ensure that 9 Indigenous right to self-determination is respected and upheld to allow Indigenous Peoples to continue to 10 carry out their cultural responsibilities to the land, for the benefit of all North Americans (Powless, 2012; 11 Etchart, 2017). | Heritage | 2520 - 2521 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 33 34 Responsibility-based philosophies of Indigenous Peoples from across the continent support the development 35 of climate change adaptation and mitigation strategies that promote responsible and respectful relationships 36 with the environment over the long term. Adapting to change, in all its forms, has since time immemorial 37 been one of the defining characteristics of Indigenous cultures on Turtle Island (the American continent). In 38 the Yucatan, one Elder explained that with regards to climate change impacts in the region, the Maya have 39 always dealt with "k'ech", or change, and that accepting and responding to change is part of the Maya 40 identity and responsibility (Sioui, 2020). Given successive failures in adequately and effectively responding 41 to climate change, it has become urgent for the rest of the human collective to (re)learn from Indigenous 42 cultures to (re)consider our responsibility/ies to the land—the world over—and to reorient our societal 43 imperatives to better respond and react to change. Such a process of learning from IK could foster the 44 development of climate change policies that promote responsible and respectful relationships with the 45 environment over the long term, and prove to be more effective and holistic. Although most inhabitants of 46 North America are non-Indigenous, it is possible and beneficial for our societies to learn to think and act in a 47 more responsibility-based way about our relations to the land, and, by extension, about climate change 48 policy. A collective commitment to protecting and advancing Indigenous territorial rights, so Indigenous 49 Peoples can continue to reassert their spiritual duty and role as stewards of their traditional territories, 50 benefits of all human and other-than-human 'Peoples'. | Heritage | 2521 - 2521 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 51 52 [END BOX 14.1 HERE] 53 54 55 14.4 Indigenous Peoples and Climate Change 56 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 14 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 14-20 Total pages: 157 1 Indigenous knowledge and science are resources for understanding climate change impacts and 2 adaptive strategies (very high confidence) (SM14.1, Table SM14.1). The Indigenous Peoples of North 3 America have and continue to contribute substantially to the growing literature, scholarship, and research on 4 climate change (Barreiro, 1999; Houser et al., 2001; Mustonen, 2005; Bennett et al., 2014; Maynard, 2014; 5 Merculieff et al., 2017; FAQI, 2019; Ijaz, 2019; BIA, 2021). For thousands of years, Indigenous Peoples 6 have developed and relied on their own knowledge systems for sustaining their health, cultures and arts, 7 livelihoods, and political security (Battiste and Henderson, 2000; Colombi, 2012; Nelson and Shilling, 8 2018). Diverse Indigenous knowledge systems in North America consider weather and climate as major 9 dimensions of understanding the relationship between society and the environment. Indigenous Peoples have 10 distinct knowledge of climate change, over extensive temporal measures (Trosper, 2002; Barrera-Bassols 11 and Toledo, 2005; Gearheard et al., 2013). The basis of this knowledge is often Indigenous Peoples' long 12 and profound relationships to the environment, that is to the ecosystems, waters, ice, lands, territories, and 13 resources in their homelands. The relationships were forged by adaptation to a particular environment and 14 involve systematic activities. Indigenous harvesters, including hunters, fishers, agriculturalists, and plant 15 gatherers, observe and monitor environmental change, and engage in systematic reflection with one another 16 about trends over short term and long-term periods (Sakakibara, 2010; Sánchez-Cortés and Chavero, 2011; 17 Kermoal and Altamirano-Jiménez, 2016; Metcalfe et al., 2020b). The holistic perspective of the interrelated 18 and interdependent nature of ecosystems is a distinct characteristic of Indigenous knowledge and often 19 contrasts with findings and results of science alone. Indigenous harvesters, agriculturalists, leaders, culture- 20 bearers, educators, and government employees develop theoretical and practical knowledge of seasonal and 21 climate change that seeks to furnish the best available knowledge and information to inform climate change 22 policy and decisions (Barrera-Bassols and Toledo, 2005; McNeeley and Shulski, 2011). Examples of 23 theoretical knowledge systems include Indigenous calendars of seasonal change and systems of laws and 24 protocols for environmental stewardship (Kootenai Culture Committee, 2015; Donatuto et al., 2020) (Box 25 14.1). | Heritage | 2521 - 2522 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 26 27 The practice and use of Indigenous knowledge systems is recognized and affirmed by the United Nations 28 Declaration on the Rights of Indigenous Peoples (UNDRIP) (UNGA, 2007), and consistent with reports and 29 guidance from UN bodies including the High Commissioner for Human Rights (Bachelet, 2019), Expert 30 Mechanism on the Rights of Indigenous Peoples (UNGA, 2015; UNGA, 2018), the Permanent Forum of 31 Indigenous Issues (Dodson, 2007; Cunningham Kain et al., 2013; Sena and UNPFII, 2013; Sena, 2014; 32 Quispe and UNPFII, 2015), and the Special Rapporteur on the Rights of Indigenous Peoples (Toledo, 2013; 33 UNGA, 2017)(Cross-Chapter Box INDIG in Chapter 18). Rights to self-determination, to control over 34 territorial development, and cultural integrity, make it important that climate scientists practice equitable 35 engagement of Indigenous knowledge and Indigenous knowledge holders. There is a growing literature of 36 success and lessons learned from co-production of knowledge between Indigenous knowledge systems and 37 diverse scientific traditions relating to climate change (Behe et al., 2018; Latulippe and Klenk, 2020; 38 Camacho-Villa et al., 2021). | Heritage | 2522 - 2522 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 46 Indigenous persons are more at risk of losing their lives due to factors that are exacerbated by climate change 47 impacts (Ford et al., 2006; Barbaras, 2014; Khalafzai et al., 2019). Indigenous Peoples' livelihood practices 48 are being distressed, interrupted, and in some cases, made entirely inaccessible. Livelihood activities known 49 and anticipated to be impacted by climate change are food security (Meakin and Kurtvits, 2009; Wesche and 50 Chan, 2010; Nyland et al., 2017), harvesting of fish, plants, and wildlife (Dittmer, 2013; Parlee et al., 2014; 51 Jantarasami et al., 2018b; ICC Alaska, 2020), agriculture (St. Regis Mohawk Tribe, 2013; Shinbrot et al., 52 2019; Settee, 2020), transportation (Swinomish Indian Tribe Community, 2010; Hori et al., 2018a; Hori et 53 al., 2018b), and tourism and recreation (ICC Canada, 2008). Indigenous Peoples have been active in 54 gathering to assess the impacts of climate change on their livelihoods, one example being the Bering Sea 55 Elders Advisory Group (Bering Sea Elders Advisory Group and Alaska Marine Conservation Council, 2011; 56 Bering Sea Elders Group, 2016). | Heritage | 2522 - 2522 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 57 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 14 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 14-21 Total pages: 157 1 Climate change impacts have harmful effects on Indigenous Peoples' public health, physical health, 2 and mental health, including harmful effects connected to the cultural and community foundations of 3 health (very high confidence). Health and climate change is a major issue for Indigenous Peoples (Ford, 4 2012; Ford et al., 2014; Gamble et al., 2016; Jantarasami et al., 2018b; Middleton et al., 2020a; Donatuto et 5 al., 2021)(14.5.6). Climate change impacts and risks affect Indigenous Peoples' health negatively in different 6 ways. Indigenous health, as tied to nutrition and exercise, is threatened when local foods are less available 7 and harvesting activities are less possible to practice (Norton-Smith et al., 2016b; Rosol et al., 2016; 8 Gonzalez et al., 2018). Indigenous Peoples experience widespread public health concerns from severe 9 droughts (Stewart et al., 2020; Schlinger et al., 2021; Wiecks et al., 2021), extreme heat (Doyle et al., 2013; 10 Campo Caap, 2018; Kloesel et al., 2018a; Meadow et al., 2018; ITK, 2019; Ute Mountain Ute Tribe and 11 Wood Environment Infrastructure Solutions Inc, 2019; Whyte et al., 2021), unpredictable precipitation 12 patterns (Chavarria and Gutzler, 2018; Tom et al., 2018; Tlingit and Haida, 2019; Schlinger et al., 2021), 13 flooding and coastal erosion (Jamestown S'klallam Tribe, 2016; Norton-Smith et al., 2016b; Puyallup Tribe 14 of Indians, 2016; Marks-Marino, 2019; Ristroph, 2019; Marks-Marino, 2020b; Schlinger et al., 2021), 15 wildfires and wildfire smoke (Edwin and Mölders, 2018; USEPA, 2018; Christianson et al., 2019a; ITK, 16 2019; Marks-Marino, 2020a; Mottershead et al., 2020; Woo et al., 2020; Wiecks et al., 2021), algal blooms 17 (Peacock et al., 2018; Gobler, 2020; Donatuto et al., 2021; Preece et al., 2021; Schlinger et al., 2021), storms 18 and hurricanes (Rioja-Rodríguez et al., 2018), influxes of invasive species (Pfeiffer and Huerta Ortiz, 2007; 19 Pfeiffer and Voeks, 2008; Voggesser et al., 2013; Bad River Band of Lake Superior Tribe of Chippewa 20 Indians and Abt Associates Inc., 2016; Scott et al., 2017; Reo and Ogden, 2018; Middleton et al., 2020a), 21 and changing production systems (Rioja-Rodríguez et al., 2018). Indigenous Peoples' mental health is at risk 22 and has already been affected negatively by climate change (Donatuto et al., 2021). Water security is one of 23 the most serious concerns to Indigenous Peoples' health and wellbeing (Vanderslice, 2011; Cozzetto et al., 24 2013a; Redsteer et al., 2013; Hanrahan et al., 2014; Chief et al., 2016; Gamble et al., 2016; Jantarasami et 25 al., 2018b; Kloesel et al., 2018a; Tom et al., 2018; Martin et al., 2020a; Arsenault, 2021). When some people 26 are less able to practice traditional, cultural, social, and family activities, they can become alienated, 27 compounding the negative effects of traumas Indigenous persons already experience. Traumas include 28 historic and continuing land dispossession, assimilation, social marginalization and discrimination, and food 29 and financial insecurities. The practice of cultural traditions are associated with education, harvesting and 30 agriculture, exercise, positive social relationships, and family life, which play foundational roles in the 31 achievement of physical, public, and mental health (Bell et al., 2010; Cunsolo Willox et al., 2015; 32 Jantarasami et al., 2018b; Norgaard and Tripp, 2019; Billiot et al., 2020b; Adams et al., 2021; Donatuto et 33 al., 2021). | Heritage | 2522 - 2523 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 33 34 Impacts on Human Systems 35 36 Increased fire activity, partly attributable to anthropogenic climate change, has had direct and indirect effects 37 on mortality and morbidity, economic losses and costs, key infrastructure, cultural resources, and water 38 resources (medium confidence), although other factors, such as increasing populations in the wildland-urban 39 interface, also contributed. During 2000–2018, significant fire events claimed 315 lives in the US (NOAA, 40 2019); the economic impacts (capital, health, indirect losses from economic disruption) from the 2018 41 California fires were US$149 billion (Wang et al., 2021). Poor air quality from fires caused increased 42 respiratory distress (very high confidence); exposure extends long distances from the fire source (Section 43 14.5.6.3). In addition to public and private property damage and loss, fires have caused irretrievable losses 44 from archaeological and historical sites (Ryan et al., 2012). Post-fire conditions have created unanticipated 45 challenges for communities' water supply operations (Bladon et al., 2014; Návar, 2015; Martin, 2016) by 46 altering water quality and availability (Smith et al., 2011; Bladon et al., 2014; Robinne et al., 2020) or public 47 safety by increasing exposure to mass wasting events after extreme rainfall events (Cui et al., 2019; Kean et 48 al., 2019). California utilities have proactively shut down parts of their electricity grid to reduce risk of fire 49 during extreme weather, and substantial numbers of people will be increasingly vulnerable to this action in 50 the coming decades (Abatzoglou et al., 2020). | Heritage | 2528 - 2528 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 49 50 In North American Arctic marine systems, rapid warming is significant, with cascading impacts beyond 51 polar regions (CCP6), and presents limited opportunities (tourism, shipping, extractive) but high risks 52 (shipping, and fishing industries, Indigenous subsistence and cultural activities) (high confidence )(Gaines et 53 al., 2018; IPCC, 2019b; Samhouri et al., 2019; Free et al., 2020; Holsman et al., 2020) (see sections 14.5.4; 54 14.5.9; 14.5.11;CCP6). Both direct hazards and indirect food web alterations from sea ice loss have 55 imperilled seabirds, marine mammals, small boat operators, subsistence hunters and coastal communities 56 (Sigler et al., 2014; Allison and Bassett, 2015; Huntington et al., 2015; Hauser et al., 2018; Raymond- 57 Yakoubian and Daniel, 2018; Dezutter et al.) (CCP6). Increasingly favourable environmental conditions due ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 14 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 14-29 Total pages: 157 1 to warming combined with shipping and other activities has raised the rate of invasive species movement 2 into the Arctic (Mueter et al., 2011). Sea ice loss due to climate change is expected to accelerate over the 3 next century (14.2, WG1 9.3.1). | Heritage | 2530 - 2531 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 9 Loss of coral habitat leads to loss of ecosystem structure, fish habitat, and food for coastal communities and 10 impacts tourism opportunities (14.5.7) (Weijerman et al., 2015a; Weijerman et al., 2015b). Without 11 mitigation to keep surface temperatures below a 2.0ºC increase by the end of the century, up to 99% of coral 12 reefs will be lost. However, 95% of reefs will still be lost even if warming is kept below 1.5ºC (high 13 confidence) (Hoegh-Guldberg et al.; Hoegh-Guldberg et al., 2019a). In Florida, by 2100, an estimated 14 US$24–55B may be lost in recreational use and value derived by people knowing the reef exists and is 15 healthy (Lane et al., 2013; Hoegh-Guldberg et al., 2019b) as coral reefs decline (14.5.9). | Heritage | 2531 - 2531 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 16 17 SLR has led to flooding, erosion and damage to infrastructure along the western Gulf of Mexico, the 18 southeast US coasts, and the southern coast of the Gulf of St Lawrence (14.2) (Daigle, 2006; Lemmen et al., 19 2016; Frederikse et al., 2020) (very high confidence). Mangroves, important nurseries for fish and climate 20 refugia for corals (Yates et al., 2014), are under threat from climate change along the east coast of Mexico 21 (Pedrozo Acuña, 2012). SLR, storm surge and attendant erosion of coastlines and barrier habitats are 22 projected to have large impacts on coastal ecosystems, maritime industries (14.5.9), urban centres and cities 23 (14.5.5) along the Gulf of Mexico, Caribbean Sea, Southeast US, the southern Gulf of St Lawrence and the 24 Pacific Coast of Mexico (Box 14.4) (Semarnat, 2014; Sweet et al., 2017; Vousdoukas et al., 2020). Coastal 25 archaeological and historical sites are especially vulnerable to SLR (Anderson et al., 2017; Hestetune et al., 26 2018; Hollesen et al., 2018). | Heritage | 2531 - 2531 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 3 4 Beaching of massive Sargassum seaweed mats (Sargassum natans and S. fluitans) have been reported across 5 the Caribbean and Gulf of Mexico from 2011-present day, affecting US and Mexico nearshore ecosystems, 6 human health and the tourism industry (Franks et al., 2016; Resiere et al.; Wang et al., 2019). Costs of beach 7 clean-up is high, with Texas spending over USD$2.9 million annually (Webster and Linton, 2013). | Heritage | 2532 - 2532 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 36 For instance, in 2015 and 2016, extensive, severe bleaching affected more than 30% of corals off the 37 southeast US and a large proportion of US Hawaiian Islands, but had moderate to no impact off the Mexican 38 Yucatan Peninsula (Frieler et al., 2013; Weijerman et al., 2015a; Weijerman et al., 2015b; Cinner et al., 39 2016; van Hooidonk et al., 2016; Hughes et al., 2018; Sully et al., 2019; Williams et al., 2019b). Some reefs 40 are exhibiting recovery following efforts focused at reducing non-climate stressors (e.g. overfishing, nutrient 41 pollution and tourism use). MHWs are increasing in intensity and frequency(Hobday et al., 2016; Smale et 42 al., 2019a) with largest increases in frequency and spatial coverage projected for the Gulf of Mexico, US 43 southern East Coast and US Pacific Northwest (Ranasinghe et al., 2021) and pose a key risk to marine 44 systems in North America (14.5.2, Ch 3, 16,). | Heritage | 2532 - 2532 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 37 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 14 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 14-40 Total pages: 157 1 2 3 Figure 14.6: Climate change impacts on North American fisheries and aquaculture 4 5 6 Warming waters and OA have impacted aquaculture production in North America (high confidence) (Figure 7 14.6) (Clements and Chopin, 2017; Reid et al., 2019; Stewart-Sinclair et al., 2020). Under climate change 8 (RCP8.5), declines in marine finfish and bivalve aquaculture become likely by mid-century (Froehlich et al., 9 2018; Stewart-Sinclair et al., 2020). Adaptation is possible but uncertain (Bitter et al., 2019; Fitzer et al., 10 2019; Reid et al., 2019), especially with increasing extreme events. Nature-based aquaculture solutions (e.g., 11 conservation aquaculture, restorative aquaculture) could aid carbon mitigation and local-level adaptation, 12 especially for seaweed and bivalve culture (Box 14.7) (Froehlich et al., 2017; Froehlich et al., 2019; Reid et 13 al., 2019; Theuerkauf et al., 2019). | Heritage | 2541 - 2542 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 23 24 25 14.5.4.4 Food and Fibre Adaptation: Agriculture, Livestock, and Forestry 26 27 Land management and horticulture approaches that preserve and improve soil structure and organic matter 28 can reduce erosion (high confidence) (Section 14.5.1, 3) (Lal et al., 2011; Bisbis et al., 2018), and preserving 29 biodiversity and water, changing planting dates, and double cropping are effective climate adaptation 30 strategies (Bisbis et al., 2018; Hernandez-Ochoa et al., 2018; Monterroso-Rivas et al., 2018; Wolfe et al., 31 2018). Traditional agriculture inherently includes climate adaptive practices that enhance biodiversity, soil 32 quality and agricultural production (e.g., multiple cultivars, heat-tolerant heritage cattle breeds) (Bermeo et 33 al.; Gomez-Aiza et al., 2017; Ortiz-Colón et al., 2018). Agroecology and agroforestry (Box 14.7) in North 34 America has expanded from (but not replaced) traditional and rural practices in Mexico (Metcalfe et al., ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 14 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 14-46 Total pages: 157 1 2020a) as a sustainable and climate-resilient alternative to industrial agriculture (Schoeneberger et al., 2017) 2 that increases productivity (by 6-65% depending on the crop), enhances microclimatesand provides co- 3 benefits for GHG mitigation (Abbas et al., 2017; Cardinael et al., 2017; Schoeneberger et al., 2017; Snapp et 4 al., 2021). Irrigation is an effective adaptation strategy in key agricultural areas (Miller, 2017; Lund et al., 5 2018) and could stabilize food security in rain-fed regions (e.g., southeastern Mexico) (Spring, 2014); water 6 allocation must balance multiple needs and rights (medium confidence) (14.5.3) (Brown et al., 2015b; Levis 7 et al., 2018; Gomez Diaz et al., 2019). Heritage livestock breeds, changing species, and precision ranching 8 technology may promote ranch and rangelands resilience (Zhao et al., 2013). In loblolly pine plantations in 9 the southern US, effective adaptation includes reducing tree density and, less effectively, shifting to slash 10 pine (Susaeta et al., 2014). Salvage logging following forest disturbances (e.g., insect outbreaks) can increase 11 timber harvest (Bogdanski et al., 2011; USDA Forst Service, 2011; Han et al., 2018; Morris et al., 2018a). | Heritage | 2547 - 2548 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 35 36 14.5.5.1.3 Sea level rise 37 SLR interacts with shoreline erosion, storm surge and wave action, saline intrusion, and coastal flooding to 38 directly threaten coastal cities and small communities in North America with impacts to public and private 39 buildings and infrastructure, port and transportation facilities, water resources (high confidence) (NOAA 40 National Weather Service, 2017; Boretti, 2019), and cultural heritage sites (Dawson et al., 2020) (Box 14.4). | Heritage | 2549 - 2549 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 28 29 14.5.5.2.3 Sea level rise 30 In the US, many people are projected to be at risk of flooding from SLR (high confidence) (Box 14.4). A 31 projected SLR of 0.9m by 2100 could place 4.2 million people at risk of inundation in US coastal counties, 32 whereas a 1.8-m SLR exposes 13.1 million people (Hauer et al., 2016). In California, under an extreme 2-m 33 SLR by 2100, US$150B (2010) of property or more than 6% of the state's GDP and 600,000 people could be 34 affected by flooding (Barnard et al., 2019). A 1-m SLR would inundate 42% of the Albemarle-Pamlico 35 Peninsula in North Carolina and incur property losses of up to US$14B (2016) (Bhattachan et al., 2018). In 36 nine southeast US states, a 1-m SLR would result in the loss of more than13,000 recorded historical and 37 archaeological sites with over 1,000 eligible for inclusion in the National Register for Historic Places 38 (Anderson et al., 2017). SLR raises groundwater levels by impeding drainage and enhancing runoff during 39 rain events (Hoover et al., 2017); coastal flooding enhances saltwater intrusion affecting drinking water 40 supply in settlements (e.g., coast of Texas) (Anderson and Al-Thani, 2016). | Heritage | 2550 - 2550 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 48 49 In Mexico, crucial coastal tourism cities such as Cancun, Isla Mujeres, Playa del Carmen, Puerto Morelos 50 and Cozumel (MX-SE) are at risk of SLR with an estimated economic impact of US$1.4 –2.3B (Ruiz- 51 Ramírez et al., 2019) (14.5.7.1.12). Negative effects of the "coastal squeeze" phenomena (generated by SLR, 52 land subsidence, sediment deficit, and current urbanization processes) have been documented on tourist 53 destinations along the coasts of Mexican Gulf of Mexico and Mexican Caribbean. Zoning, limiting 54 urbanization along the coastline, and using nature-base solutions (Box 14.7) are alternatives that could be 55 applied to improve the adaptation of these destinations (Martínez et al., 2014; Salgado and Luisa Martinez, 56 2017; Lithgow et al., 2019). | Heritage | 2550 - 2550 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 11 Projections changes are relative to 2005, which is the central year for the 1994-2014 reference period. Horizontal lines in the boxes represent the median projection, boxes represent 25th to 75th 12 percentile and whiskers the 10th to 90th 13 percentile of SLR projections from all CMIP6 models as well as other lines of evidence (see Table 9.7 in WGI.9 for 14 more details). Two SLR scenarios are provided for lower (SSP 126) and higher emissions (SSP 585), and are consistent 15 with WGI AR6 Interactive Atlas. Numbers and colors (see Table Box14.4.1 for detailed readiness definitions) on the 16 map and in the projections represent sites and status of SLR adaptation progress. Information supporting SLR 17 adaptation status is summarized in Table Box14.4.1. | Heritage | 2553 - 2553 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | Ocean Basin Site # Area/City Exposure (not exhaustive) Does the area/city have an Adaptation Plan for SLR? If so, are they taking actions to implement it? (Status) Arctic 1 Tuktoyuktuk, CA Infrastructure, municipal services, transportation, homes, 900 people Tuktoyaktuk Coastal Erosion Study completed March 2019. Additional investments in both planning and actual adaptation measures have occurred. Limited financial resources remain a barrier. (Government of Canada, 2020) ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 14 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 14-52 Total pages: 157 Atlantic 2 Prince Edward Island with Lennox Island, CA PEI: residential, industrial and commercial infrastructure. | Heritage | 2553 - 2554 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 7 Miami, US Homes, port, transportation infrastructure, tourism (hotels, restaurants, beaches) Miami Dade County released a specific SLR Strategy in 2021. Actions in the plan include elevating roads and other infrastructure, designing ways to accommodate more water in and around buildings, building on higher ground and expanding waterfront parks and canals. The plan includes a map with current and planned adaptation projects in the county (Miami�Dade County, 2021). | Heritage | 2554 - 2554 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 4 5 6 14.5.7 Tourism and Recreation 7 8 Tourism is one of the largest and fastest growing industries in North America, contributing USD$2.5 trillion 9 to North Americas' GDP in 2019 (WTTC, 2018; Duro and Turrión-Prats, 2019). The US is the world's ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 14 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 14-60 Total pages: 157 1 largest tourism economy (USD$1839 billion contribution to global GDP in 2019), Mexico is ranked 9th 2 (USD$196 billion) and Canada 13th (USD$108 billion) (WTTC, 2018). The tourism industry is both 3 impacted by climate change and significantly contributes to it through the emission of GHGs from travel and 4 activities (Becken and Hay, 2007). By 2060 under RCP8.5 Canada and the US are projected to benefit from 5 climate-induced changes in tourism expenditures of up to 92% and 21% respectively, whereas Mexico could 6 experience a 25% decrease (OECD, 2015; Scott et al., 2019a). | Heritage | 2561 - 2562 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 7 8 14.5.7.1 Observed Impacts and Projected Risks of Climate Change 9 10 14.5.7.1.1 Alpine and Nordic skiing, snowmobiling and other winter sports 11 Winter tourism activities with hard limits to adaptation, particularly those that occur at sea level where less 12 precipitation is expected to fall as snow (i.e., Nordic skiing, snowmobiling, snowshoeing), are at the highest 13 risk from climate change and may experience irreversible impacts well before 2°C of warming above pre- 14 industrial levels (high confidence) (Figure 14.9). During record warm winters, alpine ski resorts in eastern 15 Canada experienced reductions in ski season lengths of between 11 and 17 days (Rutty et al., 2017) and 16 resorts in the US Northeast (US-NE) experienced decreased skier visits by 11.6% and reductions in 17 operational profits of 33% amounting to US$40-52 million (Dawson et al., 2009). Even with advanced 18 snowmaking as an adaptation to warmer temperatures, average ski season lengths are projected to decrease 19 8% (RCP2.6, 2050s) to 73% (RCP8.5, 2080s) in Ontario, Canada (CA-ON) (Scott et al., 2019b), 12% 20 (RCP4.5, 2050s) to 22% (RCP8.5, 2080s) in Quebec, Canada (CA-QC), and 13% (RCP 4.5, 2050s) to 45% 21 (RCP 8.5, 2080s) in the US Northeast (US-NE) (Wobus et al., 2017; Scott et al., 2020). Season length for 22 snowmobiling and cross-country skiing is projected to decrease more dramatically (high confidence) by from 23 80% (RCP4.5) to 100% (RCP 8.5) by mid-century (Wobus et al., 2017) (also see CCP5). The number of 24 outdoor skating-days may decrease by 34% in Toronto and Montreal and 19% in Calgary by 2090 under 25 RCP8.5 (Robertson et al., 2015). The skating season length for the Rideau Canal in Ottawa, Canada, a 26 UNESCO heritage site attracting 1.3 million visitors annually, may decrease by 3.8±2.0 days per decade 27 with later opening dates of 2.6±1.5 days per decade (Jahanandish and Alireza, 2019). | Heritage | 2562 - 2562 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 28 29 14.5.7.1.2 Beach, coral reef, and protected areas tourism 30 Sea level rise, increased storm surge, wave action, algae blooms, extreme air temperatures, and changes in 31 wind and precipitation patterns threaten coastal tourism infrastructure, submerge beaches, erode walking 32 paths on coasts, and impact destination attractiveness, tourism demand, and recreation economies (very high 33 confidence). Warm weather tourism activities, including beach tourism, snorkelling, and national park 34 visitation will have more time to implement adaptation strategies to reduce climate risks as significant and 35 widespread impacts are not expected until 3 to 4°C of warming (Fig 14.9) (Rutty and Scott, 2015; Atzori et 36 al., 2018; Santos-Lacueva et al., 2018; Duro and Turrión-Prats, 2019). Thirty percent of hotels along the Gulf 37 of Mexico and Caribbean Sea are exposed to flooding and 66% are located on eroding beaches (Lithgow et 38 al., 2019). Coral reef cover in Akumal Bay, Mexico decreased by 79% between 2011 and 2014 (Gil et al., 39 2015; Manuel-navarrete and Pelling, 2015). The recreation value of coral reef tourism in Florida, Puerto 40 Rico, and Hawai'i is expected to decrease by 90% by mid-century under RCP8.5 (EPA, 2017) (14.4.2). | Heritage | 2562 - 2562 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 41 Wildfires and insect outbreaks have contributed to reduced desirability for tourism across forest and 42 mountain regions (Bawa, 2017; Hestetune et al., 2018; White et al., 2020). Visitors to Utah's National Parks 43 declined 0.5 to 1.5% during wildfire years between 1993 to 2015, resulting in US$2.7 to 4.5 million in lost 44 revenue (Kim and Jakus, 2019) (see Box 14.2). Trees damaged by insects have caused campground and 45 hiking trail closures in the western US and Alaska (Arnberger et al., 2018). SLR, flooding, coastal erosion, 46 changing air and sea temperatures, changing humidity, and extreme weather events are putting cultural 47 heritage sites at risks (Fatorić and Seekamp, 2017; Hollesen et al., 2018; Tetu et al., 2019). | Heritage | 2562 - 2562 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 48 49 14.5.7.1.3 Arctic tourism 50 Cruise and yacht tourism in the North American Arctic increased rapidly over the past decade as changes in 51 sea ice has expanded open water areas and season length (Johnston et al., 2016; Pizzolato et al., 2016; 52 Dawson et al., 2018). The risk of a major accident or incident among Arctic-going yachts and some 53 expedition passenger vessels is very high relative to other ships (high confidence) due to the combined 54 increases in mobile ice, especially along the Northwest Passage (Barber et al., 2018a; Howell and Brady, 55 2019; Copland et al., 2021; Lemmen et al., 2021), limited regulation for private yachts (Dawson et al., 2014; 56 Dawson et al., 2017), the propensity for cruise ships to travel into newly ice-free and poorly charted areas, 57 and the increasing number of non-ice strengthened vessels operating in the region (Dawson et al., 2018; ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 14 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 14-61 Total pages: 157 1 Copland et al., 2019; Copland et al., 2021). Compounding risks include a lack of hydrographic charting and 2 the lack of emergency response infrastructure (e.g., spill response, search and rescue, salvage) (Amap, 2017). | Heritage | 2562 - 2563 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 3 Tourism demand for polar bear viewing in Churchill, Manitoba, Canada may change due to climate-related 4 declines in polar bear health (Gil et al., 2015; Manuel-navarrete and Pelling, 2015), but may be offset by 5 'Last Chance Tourism' (LCT), a niche tourism market of individuals who explicitly seek to visit vanishing 6 landscapes and/or disappearing flora and fauna (Lemelin et al., 2010).The ethics of promoting LCT has been 7 questioned considering that more visitation to sensitive sites increases local impacts as well as travel-related 8 emissions (Groulx et al., 2016; Groulx et al., 2019). | Heritage | 2563 - 2563 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 9 10 14.5.7.2 Emerging Responses and Adaptation 11 12 Compared to other economic sectors (see section 14.5.8), the tourism industry has high adaptive capacity 13 (high confidence) (Figure 14.9). Investments in climate-resilient infrastructure within Canadian National 14 Parks have increased visitation rates during the shoulder seasons (Fisichelli et al., 2015; Lemieux et al., 15 2017; Wilkins et al., 2018), regional collaboration among US and Canadian park agencies has enhanced 16 adaptive capacity through integrated planning and management (Lemieux et al., 2015), and technological 17 advancements have reduced the vulnerability of alpine winter sports from warming temperatures (e.g., 18 snowmaking, refrigerated surfaces, chemical additives) (Rutty and Scott, 2015; Scott et al., 2019b; Scott et 19 al., 2020). Snowmaking as an adaptation strategy affects mitigation efforts by increasing the need for energy 20 and fuel (Scott et al., 2019b). | Heritage | 2563 - 2563 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 28 29 Hard and soft limits to adaptation exist in the tourism sector (Manuel-navarrete and Pelling, 2015). For 30 example, machine-made snow without the use of environmentally harmful chemical additives that are 31 banned in most jurisdictions, can only be made efficiently in temperatures below -2 °C, but projections 32 indicate warming temperatures above this threshold (Wobus et al., 2017; Scott et al., 2019a). Multi- 33 jurisdictional adaptation planning for parks and protected areas in the US has been hindered by a lack of 34 funding, communication, and funding trade-offs that could be remedied through coordination (Lemieux et 35 al., 2015). Social inequalities generated by the tourism development process must also be considered by 36 climate-related interventions to avoid the perpetuation of inequalities that may exist, particularly in less 37 developed regions and rapidly developing regions. For example, New developments in Hawai'i, Florida, 38 Quebec, and popular resort areas in Mexico have led to social inequalities through increased property taxes 39 leading to the marginalization of local residents away from these areas in favour of wealthy tourists (Manuel- 40 navarrete and Pelling, 2015) (also see 14.5.9). | Heritage | 2563 - 2563 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 41 42 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 14 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 14-62 Total pages: 157 1 2 Figure 14.9: Burning ember of the relative risks to select tourism activities in North America with and without 3 adaptation as a function of global mean surface temperature increase since pre-industrial times. Risks to tourism 4 activities include: 1) season length reductions from warming temperatures for Nordic skiing and snowmobiling, 2) 5 season length reductions from warming temperatures and precipitation changes for alpine skiing, 3) visitor experience 6 changes as a result of warming surface and ocean temperatures for beach tourism and degrading coral reef systems for 7 snorkelling, 4) visitor experience changes related to warming temperatures and changing landscape aesthetic for Parks 8 and Protected Areas. Risks assessed cover all of North America (3, 4), or are specific to certain regions (1, 2). The 9 supporting literature and methods are provided in Supplementary Materials (SM14.4). | Heritage | 2563 - 2564 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 10 11 12 14.5.8 Economic Activities and Sectors in North America 13 14 Economic sectors highly reliant on climate, such as agriculture, tourism, fisheries, and forestry, have higher 15 levels of exposure and sensitivity (high confidence) and greater overall risk to climate change compared to 16 other economic sectors such as mining, construction, and manufacturing (medium confidence). However, the 17 cascading nature of climate impacts related to trade (Box 14.5), labour productivity (14.5.8.1.5), and 18 infrastructure (14.5.8.1.2) means that there is no economic sector in North America that will be unaffected 19 by climate change (very high confidence) (Figure 14.10). For Canada, this assessment is further supported by 20 the Canadian Climate Assessment (Lemmen et al., 2021). The combined economies of Canada, Mexico and 21 the US represented ~28% of the global GDP in 2019, with the US accounting for almost 90% of the total 22 activity for North America (World Bank, 2020a). The risks posed at different GWLs for any given economic 23 activity or sector are presented in Figure 14.10. By combining expert judgement with a systematic review of 24 the literature for each sector, the information in this Figure represents a broader synthesis, especially for ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 14 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 14-63 Total pages: 157 1 sectors with a smaller literature base and at higher GWLs. The assessment of the risks of climate change on 2 tourism (14.5.7) and the interactions between sectors through trade (Box 14.5) are discussed separately. | Heritage | 2564 - 2565 |

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| IPCC | IPCC_AR6_WGII_Full_Report | 16 17 14.5.8.1.2 Transportation 18 Transportation infrastructure, including roads, bridges, rail, air, sea, and pipelines, are highly vulnerable to 19 rising temperatures, SLR, weather extremes, changing ice conditions, permafrost degradation, and flooding 20 (high confidence), resulting in damage, disruption to operations, unsafe conditions, and supply-chain impacts 21 (Board and Council, 2008; Natural Resources Conservation Service; Andrey and Palko, 2017; Jacobs et al., 22 2018; Lemmen et al., 2021) (Box 14.5). In the Mexican states of Veracruz, Tabasco, San Luis Potosí, 23 Chiapas and Oaxaca, 105,000 infrastructure sites, mostly major connecting roads, were found to be at risk of 24 flooding from tropical storms (De la Peña et al. 2018). Low water levels in the Great Lakes has severely 25 impacted US grain transport (Attavanich et al., 2013). High intensity rain events destroyed 1,000km of roads 26 and washed out hundreds of bridges and culverts in 2013 resulting in an estimated CAD$6 billion (2013 27 dollars) in damages and recovery costs in Alberta, Canada (CA-PR) (Palko and Lemmen, 2017). In 2019, the 28 rail line from Winnipeg to Churchill Manitoba, which is the only ground transportation to the community 29 and to Canada's only deep-water Arctic port, was reopened after being closed for over two years due to the 30 cumulative effects of flooding, permafrost degradation, and political challenges (Lin et al., 2020). In the US, 31 the number of heat-related train delays has increased (Bruzek et al., 2013; Chinowsky et al., 2019) and by the 32 end of the century may cause economic losses of US$25 to 45 billion (RCP4.5) or US$35 to 60 billion 33 (RCP8.5) (Chinowsky et al., 2019). Sea ice reduction in the North American Arctic has led to a rapid 34 increase in ship traffic (Huntington et al., 2015; Phillips, 2016; Pizzolato et al., 2016; Huntington et al., 35 2021b; Li et al., 2021) with cascading risks related to invasive species introduction, accident rates, black 36 carbon emissions, underwater noise pollution for marine mammals, and risks to subsistence harvesting 37 activities in Indigenous communities. (Ware et al., 2014; Council of Canadian Academies, 2016, Huntington, 38 2021; Verna et al., 2016; Chan et al., 2019) 39 40 14.5.8.1.3 Energy, oil and gas, and mining 41 Climate change is increasing the demand for electric power for cooling and threatens existing power supply 42 (high confidence) (see 14.5.5). Increased energy demand often occurs during peak energy usage and 43 especially during heat waves (Cruz and Krausmann, 2013; Leong and Donner, 2015). Cooling represented 44 74% of peak electricity demand in Philadelphia on a particularly hot day in July 2011 (Waite et al., 2017; 45 IEA, 2018b). In Canada, warming temperatures are expected to reduce demand for heating by 18 - 33% and 46 increase demand for cooling by 14 - 126% by 2070 compared to 1959-89 and 1998-2014 baseline periods, 47 respectively (Berardi and Jafarpur, 2020). The effects on hydropower are uneven across the region with the 48 potential for increases in capacity in Canada but declines of over 20% in Mexico (RCP4.5 and RCP8.5) 49 (Turner et al., 2017). Electricity demand in the US is projected to increase by 5.3 % per degree C rise in 50 temperature (Hsiang et al., 2017). Energy infrastructure, such as drilling platforms, refineries and pipelines 51 and evacuation routes are also increasingly vulnerable to higher sea levels, hurricanes, storm surges, mobile 52 multi-year sea ice, erosion, inland flooding, wildfires, and other climate-related changes (Zamuda et al., 53 2018). | Heritage | 2565 - 2565 |
| IPCC | IPCC_AR6_WGII_Full_Report | 54 55 Operational efficiency and human safety at mining and energy production sites is expected to be adversely 56 affected by increases in extreme events (Section 14.2), including storms, heavy rains, riverine flooding, and 57 wildfires (high confidence). General remoteness of many mining sites (especially in the North American ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 14 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 14-64 Total pages: 157 1 Arctic) exacerbates risks related to emergency responses to extreme events such as wildfire (medium 2 confidence). The 2016 Fort McMurray wildfire in Alberta Canada forced the evacuation of 88,000 people 3 and the shutdown of mine operations. Damages were minimal because companies had undertaken proactive 4 FireSmart interventions specifically developed for the industry (Council of Canadian Academies, 2019) (see 5 Box 14.1). Onshore oil field production in Tabasco, Mexico, which accounts for 16% of the country's daily 6 output, was interrupted by extensive flooding (Cruz and Krausmann, 2013). Two-thirds of mine operators 7 globally, including major operators in North America, have experienced production challenges related to 8 water shortages and flooding (Carbon Disclosure Project, 2013).Water availability stress due to climate 9 change is lower in Canada than in the US and Mexico and mines in Canada may be less exposed to this risk 10 (World Resourcs Institute, 2012), with some exceptions, i.e., water-intensive oil sands mining in the 11 Athabasca River basin in Canada (Leong and Donner, 2016) (also see 14.5.3).Warming temperatures also 12 has the potential to alter the nature, characteristics and quality of mineral resources such as kaolin or 13 limestone (Phillips, 2016). | Heritage | 2565 - 2566 |
| IPCC | IPCC_AR6_WGII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 14 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 14-66 Total pages: 157 1 2 3 4 Figure 14.10: Burning Ember of the relative risks to economic sectors in North America as a function of 5 projected global mean surface temperature increase since pre-industrial times. Impacts on economic sectors 6 include: 1) changing crop yield leading to economic loss for agriculture, 2) changes in the quality and quantity of timber 7 yields, 3) reductions in season length and economic viability for tourism activities, 4) increased maintenance and 8 reconstruction costs to transportation infrastructure, 5) changes in fisheries catch, 6) reduced productivity in mining and 9 energy operations, 6) reduced labour productivity in outdoor construction, and 7) increased maintenance and 10 reconstruction costs to transportation systems. Risks to economic sectors and activities were sometimes assessed across 11 all of North America (3, 4), within specific regions (1, 2), and for specific crops or species (1 - corn and soybean, 2 – 12 cod and pollock). The supporting literature and methods are provided in Supplementary Material (SM14.4). | Heritage | 2567 - 2568 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 19 20 14.5.9.3 Adaptation 21 22 Climate hazards undermine adaptation by damaging livelihoods (high confidence). Many actions that 23 enhance and promote resilient livelihoods can have substantial benefit for adaptation to climate hazards 24 (medium confidence). Livelihoods in the context of climate change are characterized by adjustments that 25 then feedback into the assets that comprise a livelihood. Social capital - in the form of household and 26 community cohesion - facilitates the development of adaptation strategies to the impacts of climate change in 27 rural and urban communities at the household level and for small groups (Barbier, 2014; Nawrotzki et al., 28 2015b; Nawrotzki et al., 2015c). Cultural capital, especially in the form of local knowledge and Indigenous 29 knowledge, can guide adaptation practices in North America (Akpinar Ferrand and Cecunjanin, 2014), 30 preserving Indigenous cultures and enhancing future adaptation and resilience (Pearce et al., 2012 2015; 31 Audefroy and Cabrera Sánchez, 2017) (Box 14.1). In Mexico, rain-water harvesting (practiced by some 32 Mayan communities) and the use of local-traditional varieties of maize have assisted in the adaptation to 33 climate impacts and promoted food security (Akpinar Ferrand and Cecunjanin, 2014; Hellin et al., 2014). | Heritage | 2573 - 2573 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 27 28 KR3: Cumulative damages from climate hazards pose a substantial risk to economic well-being and shared 29 prosperity 30 31 Climate change impacts are projected to cause large market and non-market damages (high confidence). By 32 end-of-century under higher GWL scenarios (>4°C), these damages are expected to reach several tens of 33 billions of dollars/annually in Canada and hundreds of billions/annually in the United States. Losses in 34 labour productivity and wages, and damages to coastal properties will be especially large; however, all 35 sectors in the US and most sectors in Canada are projected to see substantial relative damages on high 36 emission pathways by mid to end-of-century compared to lower emission pathways. Economic sectors with 37 hard limits to adaptation (i.e., winter tourism) or that are highly affected by climate variability (i.e., 38 agriculture and fisheries) will be at more risk at lower temperatures than other economic sectors (14.5.7; 39 14.5.8). Strategic implementation of adaptation strategies coupled with lower emissions scenarios result in 40 multi-billion-dollar reductions in economic damages (14.5.8, Box 14.6). | Heritage | 2577 - 2577 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 50 51 KR9: Risks to major infrastructure supporting commerce and trade with implications for sustainable 52 economic development, regional connections, and livelihoods 53 54 Climate change and extreme events are expected to increase risks to the North America economy via 55 infrastructure damage and deterioration (high confidence), disruption to operations, unsafe conditions for 56 workers (medium confidence), and interruptions to international and interregional supply chains (medium 57 confidence) (14.5.8, Box 14.5). These climatic impacts will have cascading implications for local livelihoods, ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 14 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 14-77 Total pages: 157 1 sustainable economic development pathways, regional connectivity and will reinforce pre-existing social 2 inequities (medium confidence). Infrastructure damage will also disrupt economic activities, including 3 manufacturing, tourism, fisheries, natural resource extraction, and energy production (high confidence) (14.5.8). | Heritage | 2578 - 2579 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 34 35 According to archaeological evidence, however, these adaptation strategies were not always sufficient during 36 times of climate-induced stress. Human remains showing the effects of malnutrition are fairly common, and 37 conflict caused in part by climate-induced shortfalls in farming has left traces that include fortified sites, sites 38 placed in defensible locations, and trauma to human bone. Larger and more hierarchical groups emerged, 39 first in Mesoamerica and then in the US Southwest, Midwest, and Southeast. These groups offered the 40 possibility of buffering poor production in one area with surplus from another, but they also tended to 41 increase inequality within their borders and often attempted to expand at the expense of their neighbours, 42 introducing new sources of potential conflict. Dense hierarchical societies also arose in other areas such as 43 the Northwest coast where agriculture was not practiced but resources such as salmon and roots were 44 abundant and either relatively constant or storable. | Heritage | 2580 - 2580 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 14 15 Still, Indigenous knowledge, and traditional knowledge among Euroamerican farming communities, provide 16 guidelines for how to cope with traditional problems. Contemporary governmental restrictions (such as legal 17 water rights allocations, international borders and tribal lands boundaries) have limited the adaptive capacity 18 that Indigenous societies developed over the centuries. Now human-caused climate forcing, if not mitigated 19 by reducing heat-trapping greenhouse gases, is expected to produce climates in North America that have no 20 local analogs in human history even as it destroys heritage sites that are sources of knowledge about 21 paleoclimates and the diverse ways of coping with them that past people have discovered. Just as past 22 peoples often avoided local climate change by moving on, in a world where mobility options are severely 23 limited a lesson from archaeology and history is that we should use our hard-won knowledge of the causes of 24 climate change to avoid creating futures with no past analogs to provide useful guidance. | Heritage | 2581 - 2581 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 32 33 Progress in Mexico on adaptation implementation at the local level has been extensive (INECC and 34 Semarnat, 2018). Activities include executing programs for relocating infrastructure in high-risk zones in 35 priority tourist sites, incorporating adaptation criteria in public investment projects that involve construction 36 and infrastructure management, water management, application of climate adaptation norms for the 37 construction of tourist buildings in coastal zones, and improving the security of key water, communication, 38 and transportation infrastructure (14.5.5, 14.5.7, 14.5.8). Additionally, local capacity and protocol to respond 39 to extreme weather events as a function of climate change have been integrated more regularly into 40 community-based hazard mitigation plans. States and municipalities in Mexico must have climate policies 41 that are consistent with the guidelines of national strategies (see 14.7.1.5) and state-level programs on 42 climate change, in addition to other state and municipal laws. As a result, these entities have developed and 43 implemented early warning systems designed to protect the population from climate-related risks, such as 44 strong storms and hurricanes (INECC and Semarnat, 2018). | Heritage | 2584 - 2584 |

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| IPCC | IPCC_AR6_WGII_Full_Report | jurisdictional boundaries Marine species mortality events Freshwater Resources (14.5.3) Forecasting and warning of harmful algal blooms (HABs) that affect water quality Reduced human exposure to the increased risk of toxins from HABs in the Great Lakes M L�M L- M L- M Financial resources required to enhance water treatment facilities to deal with HABs; technological innovation to improve treatment and removal of HABs; closure of recreational water use Severe human health effects; mortality of aquatic species ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 14 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 14-86 Total pages: 157 Water Availability (14.5.3) Water allocation policies reassessed to enhance equity, sustainability and flexibility in times of shortage through sharing agreements, improved groundwater regulation and voluntary water transfers US Colorado River interstate shortage sharing agreement H H M L�M Complex legal and administrative challenges, heightening lengthy disputes and costly interstate legal battles Depletion of finite groundwater resources and reduced flow in hydrologically connected rivers Food & Fibre (14.5.4) Improved climate resilience through increasing income and harvest/crop portfolio diversification Fishing communities in the US-SW and US-NE through nature-based aquaculture solutions (Messier et al., 2019; Rogers et al., 2019; Young et al., 2019; Fisher et al., 2021) H H M�H M Lack of high resolution and locally tailored climate change information Collapse of fisheries and loss of crops due to excessive warming and extreme events Cities & Infrastructure (14.5.5) Consideration of the value of green infrastructure and natural assets to meet a range of adaptation needs related to flooding, extreme urban heat, SLR, drought Municipal Natural Assets Initiative (MNAI) assists Canadian municipalities to integrate natural assets in financial planning and asset management programs and consider projected climate changes (Municipal Natural Assets Initiative, 2018) H H M L�M Organizations' willingness to take on solutions that are emergent and less tested; capacity for municipalities to undertake the development and assessment this new infrastructure Rate and magnitude of climate changes exceed capacity of natural/green infrastructure to cope Health & Communities (14.5.5, 14.5.6) Access to green spaces, cooler infrastructure, and cooling stations The heatwave plan for Montreal includes visits to vulnerable populations, cooling shelters, monitoring of heat-related illness, and extended hours for public pools (Lesnikowski et al., 2017) H H L�M L- M Lack of effective warning and response systems, ability to reach at-risk populations, building designs, enhanced pollution controls, urban planning strategies, and affordable, resilient health infrastructure Extreme increase heat�related mortality and morbidity Tourism & recreation (14.5.7) Diversification of winter-focused recreation and tourism opportunities Investments in climate-resilient infrastructure within Canadian National Parks have increased visitation rates during the shoulder seasons (Fisichelli et al., 2015; Lemieux et al., 2017; Wilkins et al., 2018) H H M L Social inequalities generated by the tourism development process not considered, such as increased property taxes leading to the marginalization of local residents in favour of wealthy tourists Lack of precipitation that falls as snow particularly in lower elevation areas Commerce & transportation (14.5.8) Improved engineering and technological For roads, changing pavement mixes to be more tolerant to H H M L Lack of financial resources to build climate-resilient Extreme events may cause ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 14 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 14-87 Total pages: 157 solutions, in addition to innovative policy, planning, management, and maintenance approaches enhance climate resilience for transportation & related commerce heat or frost heaving, expanding drainage capacity, reducing flood risks, enhancing travel advisories and alerts, elevating or relocating new infrastructure where feasible and changing infrastructure design requirements (Natural Resources Conservation Service, 2008; EPA, 2017; Pendakur, 2017). | Heritage | 2587 - 2589 |
| IPCC | IPCC_AR6_WGII_Full_Report | Sector NbS Actions Benefits References ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 14 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 14-92 Total pages: 157 Coasts Conservation and restoration of barrier habitats, salt marshes, mangroves, coral and oyster reefs, sand dunes, and river deltas; combined natural and built infrastructure, e.g., oyster reef in front of breakwall Wave attenuation; erosion and flood reduction from storm events exacerbated by SLR; novel, created habitats, connectivity; recreation, quality of life (Borsje et al., 2011; Scyphers et al., 2011; Cheong et al., 2013; Pinsky et al., 2013a; Temmerman et al., 2013; Ferrario et al., 2014; Möller et al., 2014; Rodriguez et al., 2014; Spalding et al., 2014; Yates et al.; EPA, 2015b; Grenier et al., 2015; Brandon et al., 2016; Herr and Landis, 2016; Narayan et al., 2016; Sasmito et al., 2016; Ward et al., 2016; Aerts et al., 2018; Beck et al., 2018a; Morris et al., 2018b; Moudrak et al.; Reguero et al., 2018; Sutton-Grier et al., 2018) Watershed approaches such as protecting and restoring forests and wetlands in coastal watersheds, adopting stream buffers in agricultural areas (see agriculture below) Create a less flashy/variable hydrology; reduce sediment, nutrient, hazardous chemical input to coastal waters and reduce eutrophication and other water quality impairments, notably in in deep waters where fish seek refuge from rising sea surface temperatures (Deutsch et al., 2015b) Boesch 2019,CENR 2010 Aquaculture Controlled culture of fish, bivalves, corals and other marine species Enhance, restore and reduce pressure on wild species and ecosystems; Restore threatened species such as coral reef species. | Heritage | 2593 - 2594 |
| IPCC | IPCC_AR6_WGII_Full_Report | 30 Affiliated Tribes of Northwest Indians, 2020: American Indian Communities in the Contiguous United States: Unmet 31 infrastructure needs and the recommended pathway to address a fundamental threat to lives, livelihoods, and 32 cultures. | Heritage | 2597 - 2597 |
| IPCC | IPCC_AR6_WGII_Full_Report | 15 Climate change is also affecting settlements and infrastructure, health and wellbeing, water and food 16 security, and economies and culture, especially through compound events (high confidence). As of 2017, an 17 estimated 22 million people in the Caribbean live below 6 metres elevation and 50% of the Pacific's 18 population lives within 10 km of the coast along with ≥50% of their infrastructure concentrated within 500 19 metres of the coast {15.3.4.1, 15.3.4.2, 15.3.4.3, 15.3.4.4, 15.3.4.5, 15.3.4.7}. | Heritage | 2662 - 2662 |

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| Organisation | Document | Quotation Content | Codes | Page |
|---|---|---|---|---|
| IPCC | IPCC_AR6_WGII_Full_ Report | 20 21 Tropical cyclones are severely impacting small islands (high confidence). The TC intensity and 22 intensification rates at a global scale have increased in the past 40 years with intensity trends generally 23 remaining positive. Intense TCs including categories 4 and 5 TCs have threatened human life and destroyed 24 buildings and infrastructural assets in small islands in the Caribbean and the Pacific. Among 29 Caribbean 25 islands, 22 were affected by at least one category 4 or 5 TC in 2017. TC Maria in 2017 destroyed nearly all 26 of Dominica's infrastructure and losses amounted to over 225% of the annual GDP. Destruction from TC 27 Winston in 2016 exceeded 20% of Fiji's current GDP. TC Pam devastated Vanuatu in 2015 and caused 28 losses and damages to the agricultural sector valued at USD 56.5 million (64.1% of GDP). Coast-focused 29 tourism is already extremely impacted by more intense TCs. {WGI 11.7.1, 12.4.7 15.2.1, 15.3.3.1, 15.3.3.3, 30 15.3.4.1, 15.3.4.2, 15,3.4.4, 15.3.4.5}. | Heritage | 2662 - 2662 |
| IPCC | IPCC_AR6_WGII_Full_ Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 15 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 15-5 Total pages: 107 1 Suandaland regions by 2100 for > 3°C warming {15.3.3.3}. This is likely to decrease the provision of resources 2 (e.g. potable water) to the millions of people living on small islands, resulting in impacts upon settlements and 3 infrastructure, food and water security, health, economies, culture, and migration (high confidence) {15.3.3.2, 4 15.3.3.3, 15.3.4.1, 15.3.4.2, 15.4.3, 15.3.4.4, 15.3.4.5, 15.3.4.6, 15.3.4.7}. | Heritage | 2663 - 2664 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 18 19 Future Risks 20 21 The reduced habitability of small islands is an overarching significant risk caused by a combination of 22 several Key Risks facing most small islands even under a global temperature scenario of 1.5 degrees 23 (high confidence). These are loss of marine and coastal biodiversity and ecosystem services; submergence 24 of reef islands); loss of terrestrial biodiversity and ecosystem services ; water insecurity ; destruction of 25 settlements and infrastructure ; degradation of health and well-being ; economic decline and livelihood 26 failure); and loss of cultural resources and heritage. Climate-related ocean changes, including those for slow 27 onset events, and changes in extreme events are projected to cause and/or amplify Keys Risks in most small 28 islands. Identification of Key Risks facilitates the selection of optimal context-specific adaptation options. | Heritage | 2664 - 2664 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 38 39 The unavailability of up-to-date baseline data and contrasting scenarios/temperature levels continue 40 to impair the generation of local-to-regional observed and projected impacts for small islands, 41 especially those that are developing nations (high agreement). Climate model data based on the most 42 recent suite of scenarios (RCPs and especially SSPs) are still not widely available to primary modelling 43 communities in most small island developing nations (high agreement). Coastal sites of small islands are not 44 well-represented in global gridded population and elevation datasets, thereby making estimation of 45 population exposure to SLR difficult. The lack of data continues to impede the development of robust 46 impacts-based modelling output (e.g. for terrestrial biodiversity). Downscaling is pivotal for small islands 47 due to their high diversity which makes generalisation invalid. | Heritage | 2665 - 2665 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 20 21 Despite storm-induced erosion prevailing along some shoreline sections, recent studies reaffirmed the 22 contribution of TC and ETC waves to coastal and reef island vertical building through massive reef-to-island 23 sediment transfer (high confidence). For example, TC Ophelia (1958) and Category 5 TC Fantala (2016), 24 which respectively eroded the islands of Jaluit Atoll, Marshall Islands (Ford and Kench, 2016), and Farquhar 25 Atoll, Seychelles (Duvat et al., 2017c), also contributed to island and beach expansion. Likewise, tropical 26 depressions can have constructional effects, as reported on Fakarava Atoll, French Polynesia (Duvat et al., 27 2020b). On Saint-Martin/Sint Maarten and Saint-Barthélemy, the 2017 hurricanes, which caused marked 28 shoreline retreat at most beach sites, also allowed beach formation and beach ridge development along some 29 natural coasts (Duvat et al., 2019a; Pillet et al., 2019). Similarly, El Niño and La Niña were involved in rapid 30 and highly contrasting shoreline changes (high confidence), including reef island accretion in the Ryukyu 31 Islands, Japan (Kayanne et al., 2016), beach shifts on Maiana and Aranuka Atolls, Kiribati (Rankey, 2011), 32 and beach erosion on Hawaii, USA (Barnard et al., 2015). These contrasting shoreline responses were 33 respectively due to coral reef degradation from past bleaching events providing material to islands, wave 34 directional shifts, and increased wave energy. The role of bleaching events in increasing short-term sediment 35 generation in atoll contexts was confirmed by a study conducted on Gaafu Dhaalu Atoll, Maldives, which reported an increase of sediment production from ~0.5 kg CaCO3 m–2 yr-1 to ~3.7 kg CaCO3 m-2 yr-1 36 37 between 2016 (pre-bleaching) and 2019 (bleaching + 3 years) (Perry et al., 2020). | Heritage | 2674 - 2674 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 24 25 Satellite data and local field studies at 3351 sites in 81 countries including small islands show that not all 26 coral reefs are equally exposed to severe temperature stress events, and even similar coral reefs exposed to 27 similar conditions show local and regional variation and species-specific responses (Sully et al., 2019). There 28 is great variability in terms of sensitivity of corals to climate change, as also demonstrated in the Comoros 29 Archipelago (Cowburn et al., 2018), in the Pacific (Fox et al., 2019; Mollica et al., 2019; Romero-Torres et 30 al., 2020) and globally (Sully et al., 2019; McClanahan et al., 2020). It has been hypothesised that low- 31 latitude tropical reefs bleached less than those in higher latitudes because: (i) of the geographical differences 32 in species composition, (ii) of the higher genotypic diversity at low latitudes, and (iii) some corals were pre- 33 adapted to thermal stress because of consistently warmer temperatures at low latitude prior to thermal stress 34 events (Sully et al., 2019). However, latitudinal variation was not reported in other global surveys of coral 35 bleaching occurrence (Donner et al., 2017; Hughes et al., 2017a; Hughes et al., 2017b; McClanahan et al., 36 2019). Ainsworth et al. (2016) and Ateweberhan et al. (2013) showed that coral bleaching can be mitigated 37 by pre-exposure to elevated temperatures. Regionally, recovery is also highly variable. While some reefs in 38 the Seychelles and Maldives were shown to recover to pre-disturbance levels of coral cover after previous 39 bleaching events (Box 15.1; Pisapia et al., 2016; Koester et al., 2020), other reefs underwent seemingly 40 permanent regime shifts toward domination by fleshy macro algae (Graham et al., 2015), or major declines 41 in carbonate budgets, and thus the capacity of reefs to sustain vertical growth under rising sea levels (Perry 42 and Morgan, 2017). | Heritage | 2675 - 2675 |

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|---|---|---|---|---|
| IPCC | IPCC_AR6_WGII_Full_Report | 11 12 Since 2011, the Caribbean region has been experiencing unprecedented influxes of the pelagic seaweed 13 Sargassum. These extraordinary sargassum 'blooms' have resulted in mass strandings of sargassum 14 throughout the Lesser Antilles, with significant damage to coastal habitats, mortality of seagrass beds and 15 associated corals (van Tussenbroek et al., 2017), as well as consequences for fisheries and tourism. Whether 16 or not such events are related to long-term climate change remains unclear, however it has been suggested 17 that the influx may be related to strong Amazon discharge, enhanced West African upwelling, together with 18 rising seawater temperatures in the Atlantic (low confidence) (Oviatt et al., 2019; Wang et al., 2019). Since 19 2011, the Pacific atoll nation of Tuvalu has also been affected by algal blooms, the most recent being a large 20 growth of Sargassum on the main atoll of Funafuti, and this phenomenon has been related to anthropogenic 21 eutrophication and high seawater temperatures (De Ramon N'Yeurt and Iese, 2014). | Heritage | 2676 - 2676 |
| IPCC | IPCC_AR6_WGII_Full_Report | 50 51 Marine flooding is expected to destroy habitats of coastal species, particularly range-restricted coastal and/or 52 single-island endemics (many already listed as at least 'threatened' by the International Union for 53 Conservation of Nature [IUCN]) within the limited terrain on atoll islands. These species have limited 54 opportunities to accommodate such direct impacts of climate change apart from shifting further inland or to 55 other neighbouring atolls which might have favourable habitat. However, fragmentation of habitat due to 56 anthropogenic activity may hinder migration further inland, while shifting to neighbouring islands is not 57 viable due to the water barrier between islands (high confidence) (Bellard et al., 2013b; Wetzel et al., 2013; ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 15 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 15-22 Total pages: 107 1 Kumar and Tehrany, 2017). Additionally, migratory birds, which use small islands (e.g. atolls) for stopovers 2 or breeding/nesting sites, are projected to become impacted. Within the Mediterranean and Caribbean, 3 significant losses to coastal wetlands - critical habitat for migratory birds has already been observed, with 4 further significant habitat losses, redistribution and changes in quality being projected across island systems 5 such as the Bahamas (Caribbean) and Sardinia (Mediterranean) (Vogiatzakis et al., 2016; Wolcott et al., 6 2018). | Heritage | 2680 - 2681 |
| IPCC | IPCC_AR6_WGII_Full_Report | 41 Continued high rates of habitat loss and degradation have been reported for many small islands as natural 42 habitats continue to be cleared to meet increasing demands upon natural resources from rising human 43 populations, agriculture, urbanisation, unsustainable tourism, overgrazing and fires. This increases the 44 vulnerability of ecosystems within especially oceanic islands — where isolation has given rise to high levels 45 of endemism but simple biotic communities, with low functional redundancy (Box CCP1.1). There is high 46 confidence that climate change may exacerbate the effects of this habitat loss upon the biodiversity of these 47 islands as the climate refugia (Table 15.3) and the upslope shifts of range-restricted, dispersal-limited and 48 poorly competitive species, confined within narrow latitudinal (and decreasing altitudinal) gradients, are 49 increasingly challenged by fragmented and degraded landscapes (e.g., Struebig et al., 2015a; IPBES, 2019). | Heritage | 2681 - 2681 |
| IPCC | IPCC_AR6_WGII_Full_Report | 55 56 Analyses of historical and current threats indicate that IAS and disease have been the primary drivers of 57 insular extinctions in modern history (Bellard et al., 2016). Impacts of IAS on islands are projected to ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 15 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 15-23 Total pages: 107 1 increase with time due to synergies between climate change and other traditional drivers such as increasing 2 global trade, tourism, agricultural intensification, over exploitation and urbanisation (Bellard et al., 2014; 3 Russell et al., 2017). Changing climate conditions may not necessarily increase the rate of IAS introductions 4 but is expected to improve chances of IAS establishment via (i) altering IAS transport and introduction 5 mechanisms, (ii) increasing the impacts and distributions of existing IAS and (iii) altering the effectiveness 6 of existing control strategies (Hellmann et al., 2008; Russell et al., 2017). These are likely to enhance IAS 7 impacts on islands including: restructuring of ecological communities leading to declines and 8 extinctions/extirpations in flora and fauna, habitat degradation, declining ecosystem functioning, services 9 and resilience, and in extreme cases, potential community homogenisation (high confidence) (Russell and 10 Blackburn, 2017; IPBES, 2019). Given the high degree of endemicity within oceanic islands and their 11 associated vulnerabilities, such exacerbation by changing climate pose a serious threat to decreasing global 12 biodiversity (medium to high confidence) (van Kleunen et al., 2015). | Heritage | 2681 - 2682 |
| IPCC | IPCC_AR6_WGII_Full_Report | 57 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 15 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 15-26 Total pages: 107 1 15.3.4.3 Water Security 2 3 Climate change impacts on freshwater systems frequently exacerbate existing pressure, especially in 4 locations already experiencing water scarcity (Section 15.3.3.2 and Cross-Chapter Box INTERREG in 5 Chapter 16; Schewe et al., 2014; Holding et al., 2016; Karnauskas et al., 2016), making Water Security a 6 Key Risk (KR4 in Figure 15.5) in small islands. Small islands are usually environments where demand for 7 resources related to socio-economic factors such as population growth, urbanisation and tourism already 8 place increasing pressure on limited freshwater resources. In many small islands, water demand already 9 exceeds supply. For example, in the Caribbean, Barbados is utilising close to 100% of its available water 10 resources and St. Lucia has a water supply deficit of approximately 35% (Cashman, 2014). On many 11 Mediterranean islands, water demand regularly outstrips supply as a result of low average precipitation 12 coupled with increasing water demand from economic activities such as irrigated agriculture and tourism 13 (Hof et al., 2014; Papadimitriou et al., 2019). | Heritage | 2684 - 2685 |

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| IPCC | IPCC_AR6_WGII_Full_Report | 48 49 Many small-island economies are sustained by tourism and have invested heavily in associated infrastructure 50 and capacity building (Cannonier and Burke, 2018). Some rural island communities have become dependent 51 on tourism to the point that it would be difficult to revert to subsistence living (Lasso and Dahles, 2018). | Heritage | 2687 - 2687 |
| IPCC | IPCC_AR6_WGII_Full_Report | 52 Coast-focused (beach-sea) tourism in island contexts is already being impacted by beach erosion, elevated 53 high SST causing coral bleaching, and associated marine-biodiversity loss, as well as more intense TCs 54 (Tapsuwan and Rongrongmuang, 2015; Parsons et al., 2018; Wabnitz et al., 2018). The Covid-19 pandemic 55 travel disruption significantly affected Caribbean islands tourism sector by reducing incomes that would 56 have been used to enhance climate resilience (Sheller, 2020). Many tourism interests downplay the impacts 57 and future risks from climate change (Shakeela and Becken, 2015), a position that may be borne out by ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 15 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 15-29 Total pages: 107 1 sustained/rising demand for small island vacationing in some locales (Katircioglu et al., 2019). A way 2 forward is for island tourism to emphasize its low-carbon and sustainable attributes, and to encourage 3 smaller-scale eco-friendly holiday opportunities (Lee et al., 2018), in other words for island nations to 4 embrace a 'blue economy' in line with SDG14 to conserve and utilise their oceans for sustainable futures 5 (Hampton and Jeyacheya, 2020; Hassanali, 2020). | Heritage | 2687 - 2688 |
| IPCC | IPCC_AR6_WGII_Full_Report | 42 43 Even where settlement locations and livelihoods remain secure, an increase in health diseases, decrease in 44 the availability of potable water, and increasing exposure to extreme events may reduce habitability (Section 45 15.3.4.9.2; Campbell and Warrick, 2014; Storlazzi et al., 2018). For example, the Fijian coastal community 46 of Vunidogoloa made the decision to relocate in response to regular inundation during high tides. Raising 47 houses on stilts and constructing a seawall failed to prevent regular flood damage to buildings and the entire 48 community eventually relocated as a 'last resort' adaptation measure to a site within customary land. The 49 availability of customary land for the new site was a key factor of success in this relocation example ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 15 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 15-31 Total pages: 107 1 although this will not guarantee success in every case as relocation may expose communities to new risks 2 (McNamara and Des Combes, 2015; Piggott-McKellar et al., 2019a). | Heritage | 2689 - 2690 |
| IPCC | IPCC_AR6_WGII_Full_Report | 3 4 15.3.4.7 Culture 5 6 Small island societies have developed IKLK based responses to living in dynamic environments susceptible 7 to climate variability and extremes, which are based in broader systems of culture and heritage (high 8 confidence) (Barnett and Campbell, 2010; Lazrus, 2015; Nunn et al., 2017b; Bryant-Tokalau, 2018b; Nalau 9 et al., 2018b; Perkins and Krause, 2018). As expanded upon in Section 15.6.5 cultural resources are thought 10 to play an important role in climate change adaptation on small islands through contributing to adaptive 11 capacity and resilience (McMillen et al., 2014; Petzold and Ratter, 2015; Nunn et al., 2017b; Warrick et al., 12 2017; Falanruw, 2018; Mondragón, 2018; Neef et al., 2018; Parsons et al., 2018; Perkins and Krause, 2018; 13 Hagedoorn et al., 2019; 2020a) (robust evidence, medium agreement). Thus, loss of culture (KR8 in Figure 14 15.5) threatens adaptive capacity. | Heritage | 2690 - 2690 |
| IPCC | IPCC_AR6_WGII_Full_Report | 27 28 The unquantifiable and highly localised cultural losses resulting from climate drivers are less researched and 29 less acknowledged in policy than physical and economic losses (Karlsson and Hovelsrud, 2015; Thomas and 30 Benjamin, 2018a). In the Bahamas, prolonged displacement of the entire population of Ragged Island 31 following Hurricane Irma (2017) highlighted the cultural losses that can result from climate-induced 32 displacement from ancestral homelands. Threats to identity, sense of place and community cohesion resulted 33 from displacement, although all were important foundational features of the Islanders' self-initiated 34 rehabilitation efforts and eventual return. Nonetheless, non-economic losses were not accounted for by 35 policy addressing displacement (Thomas and Benjamin, 2018a). In the case of Monkey River Village in 36 Belize, coastal erosion is threatening the community's cemetery. Residents place significant spiritual and 37 emotional value on the cemetery which serves important community functions, and thus, threats to it are 38 perceived to be serious and necessary to be taken into account in any planned response (Karlsson and 39 Hovelsrud, 2015). A similar situation exists on Carriacou in the West Indies where culturally and historically 40 significant archaeological sites are being lost due to coastal erosion caused by a combination of sand mining 41 and extreme climate-ocean events exacerbated by SLR (Fitzpatrick et al., 2006). | Heritage | 2690 - 2690 |
| IPCC | IPCC_AR6_WGII_Full_Report | 42 43 Population and settlement concentration in coastal areas and high exposure to climate-driven coastal hazards 44 on small islands mean that threats to tangible cultural heritage (archaeological sites, buildings, historic sites, 45 UNESCO World Heritage Sites etc.) are high (Marzeion and Levermann, 2014; Reimann et al., 2018), 46 although few studies examine this issue specifically in a small island context. On the island of Barbuda, 47 archaeological sites containing important information on historical ecology and climatic shifts are at risk 48 from coastal erosion and hurricanes. This loss of heritage represents identity loss, as "learning about the past 49 is a crucial exploration of self that grounds and connects people to places" (Perdikaris et al., 2017)(p. 145). | Heritage | 2690 - 2690 |
| IPCC | IPCC_AR6_WGII_Full_Report | 50 Loss and damage to heritage sites may also impact tourism and thus have significant economic impacts for 51 narrow small island economies (Section 15.3.4.5). | Heritage | 2690 - 2690 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 20 21 22 The 1997-1998 ENSO event was severe in the Maldives and as a result the living coral cover dropped to 23 <10% (Bianchi et al., 2003). Recovery was still in progress in 2004 when the tsunami caused further 24 (although not quantitatively assessed (Gischler and Kikinger, 2006)) damage to the reef ecosystem. Post- 25 1998 recovery ultimately took 15 years, (i.e., longer than following the 1987 ENSO event, after which 26 recovery had only taken a few years) and also longer than in the neighbouring undisturbed Chagos atolls, 27 thereby suggesting the alteration of the recovery capacity of the reef ecosystem by human-induced reef 28 degradation and climate change (Morri et al., 2015; Pisapia et al., 2017). Mid-2016, a new ENSO event 29 occurred, which reduced living coral cover by 75% (Perry and Morgan, 2017). Future recovery of the reef 30 ecosystem, which is critical to both current livelihoods and economic activities (especially diving-oriented 31 tourism and fishing) and to long-term island persistence, will mainly depend first on the frequency and 32 magnitude of future bleaching events, which are expected to increase due to ocean warming, and second on 33 the highly variable effects of anthropogenic disturbances locally (Perry and Morgan, 2017; Pisapia et al., 34 2017; Duvat and Magnan, 2019b). | Heritage | 2691 - 2691 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 22 23 The loss of mangroves (Branoff, 2018; Walcker et al., 2019; Taillie et al., 2020) and terrestrial forests 24 (Eppinga and Pucko, 2018; Feng et al., 2018; Hu and Smith, 2018; Van Beusekom et al., 2018) exacerbated 25 the cyclone-induced economic crisis. In the most affected islands, the destruction of buildings and 26 outmigration generated a significant loss of tangible (e.g., museums) and intangible (e.g., traditional artistry) 27 cultural heritage (Boger et al., 2019). Prolonged displacement of entire island populations (e.g., Ragged 28 Island, the Bahamas; Barbuda) caused “non-economic loss and damage”, including threats to health and ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 15 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 15-34 Total pages: 107 1 well-being, and loss of culture, sense of place and agency (Thomas and Benjamin, 2019), which may further 2 exacerbate the long-term vulnerability of concerned communities. | Heritage | 2692 - 2693 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 24 25 These KRs include loss of marine and coastal biodiversity and ecosystem services (high confidence) (KR1; 26 for details on KR coverage, see Section 15.3.3.1); submergence of reef islands (low confidence) (KR2; 27 Section 15.3.3.1.1); loss of terrestrial biodiversity and ecosystem services (high confidence) (KR3; Section 28 15.3.3.3); water insecurity (medium-high confidence) (KR4; Section 15.3.4.3); destruction of settlements and 29 infrastructure (high confidence) (KR5; Section 15.3.4.1); degradation of human health and well-being (low 30 confidence) (KR6; section 15.3.4.2); economic decline and livelihood failure (high confidence) (KR7; 31 Sections 15.3.4.4 and 15.3.4.5); and loss of cultural resources and heritage (low confidence) (KR8; Section 32 15.3.4.7). | Heritage | 2694 - 2694 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 48 49 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 15 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 15-36 Total pages: 107 1 2 Figure 15.5: Key Risks in small islands. KR1 to 8 are interconnected as shown by arrows, which causes risk 3 accumulation leading to reduced island habitability. The main interconnections are shown in this figure: for example, 4 loss of marine and coastal and terrestrial biodiversity and ecosystem services (KR1 and KR3, respectively) are 5 projected to cause the submergence of reef islands (KR2), water insecurity (KR4), destruction of settlements and 6 infrastructure (KR5), degradation of human health and well-being (KR6), economic decline and livelihood failure 7 (KR7), and loss of cultural resources and heritage (KR8). Importantly, Key Risks result from both direct effects (e.g. | Heritage | 2694 - 2695 |
| IPCC | IPCC_AR6_WGII_Full_ Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 15 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 15-41 Total pages: 107 1 2 3 4 Figure 15.7: Adaptation measures implemented to reduce coastal risks in small islands. Panel 1 provides examples of 5 implementation of different types of measures aimed at reducing coastal erosion and flooding. The measures include no 6 response (no intervention, widespread in small islands), hard protection through the construction of engineering-based 7 structures, accommodation through dwelling and infrastructure raising, planned retreat, advance (i.e. especially island 8 raising) and ecosystem-based measures, in three small island regions, the Indian and Pacific Oceans and Caribbean. It 9 highlights the prevalence of no response, hard protection and the increasing use of ecosystem-based measures. Based on 10 the example of two beach sites in Mauritius (Mon Choisy in the north and Saint-Félix in the south), panel 2 shows that 11 the measures used at a given coastal site evolve over time (e.g., from no response to hard protection, and then planned 12 retreat and ecosystem-based measures) and that recent DRR (Saint-Félix) and adaptation (Mon Choisy) projects often 13 combine several types of measures, including retreat and ecosystem-based measures (Duvat et al., 2020a). Together, 14 panels 1 and 2 emphasize the diversity and increasing complexity of the measures implemented in small islands. | Heritage | 2699 - 2700 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 25 26 15.5.6 Livelihood Responses 27 28 Communities across small islands are adapting to the impacts of climate change across a range of livelihood 29 activities. Coastal fishers have adapted by employing several activities ranging from diversification of 30 livelihoods to changing fishing grounds and considering weather insurance (Blair and Momtaz, 2018; 31 Lemahieu et al., 2018; Karlsson and McLean, 2020; Turner et al., 2020). In Antigua and Vanuatu, fishers 32 have undertaken adaptation in response to increases in air and ocean temperature, increases in wind and 33 changes in rainfall. In Antigua, adaptation strategies amongst coastal fishers have included investments in 34 improved technologies and equipment, changing fishing grounds, and seeking better training and education 35 (Blair and Momtaz, 2018). In Efate (Vanuatu) the majority (87%) of the fishermen used livelihood 36 diversification as an adaptation strategy whereas 53% also searched for new fishing areas as a result of the 37 changing conditions (Blair and Momtaz, 2018). In Southwest Madagascar, due to deteriorated reef 38 conditions, coastal fishermen now go further offshore to catch fish or have adapted their fishing techniques, 39 while others closer to the tourism markets, have opted for livelihood diversification (Lemahieu et al., 2018). | Heritage | 2701 - 2701 |

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| Organisation | Document | Quotation Content | Codes | Page |
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| IPCC | IPCC_AR6_WGII_Full_Report | 12 13 The tourism sector is increasingly a major source of cash-based livelihoods across small islands. Despite the 14 high vulnerability and sensitivity of island tourism to climate change at a national scale (Scott et al., 2019), 15 there is evidence from the South Pacific that local tourism operators' adaptive capacity is high due to socio- 16 cultural factors. In Samoa, adaptive capacity consists of accommodation providers' social networks, 17 resources, past experiences and understanding of environmental conditions, and remittances as a form of 18 informal insurance (Parsons et al., 2017). The adaptive capacity of Tongan tour operators is strengthened by 19 high climate change awareness, strong social networks and remittances as well as perceived high resilience 20 against climate change (van der Veeken et al., 2016). | Heritage | 2702 - 2702 |
| IPCC | IPCC_AR6_WGII_Full_Report | 21 22 Evidence from Vanuatu shows that climate risk to tourism destinations is influenced by multiple, 23 interconnected economic, socio-cultural, political, and environmental factors suggesting that holistic 24 approaches are needed to reduce risk and avoid negative knock-on effects (Loehr, 2019). Tourism can 25 strengthen mechanisms that reduce vulnerability and increase adaptive capacity of the wider destination, 26 such as providing adaptation finance, investing in education and capacity building, and working with nature 27 (Loehr, 2019).Examples include numerous EBA initiatives in the Caribbean including Marine Protected 28 Areas in St. Lucia and Jamaica (Mycoo, 2018a). In Vanuatu, tourism businesses are engaged in establishing 29 Marine Protected Areas to address multiple risks from climate change, population growth and development 30 (Loehr et al., 2020). In the Seychelles, coral restoration programmes and mangrove reforestation are 31 promoted through public-private partnerships, generating new opportunities for wetland-tourism livelihoods 32 (Khan and Amelie, 2015). | Heritage | 2702 - 2702 |
| IPCC | IPCC_AR6_WGII_Full_Report | 33 34 The willingness of tourism businesses to finance adaptation measures varies. Islands have developed 35 building codes which consider impacts from sea level rise but these are often not enforced enforced (Hess 36 and Kelman, 2017). In cases where tourist resorts have been part of climate adaptation projects, such as 37 funding for hard coastal protection infrastructure, the resort owners find that these diminish the aesthetics of 38 the beach destination (Crichton and Esteban, 2018). Adaptation taxes and levies imposed on tourism can 39 provide funding (Mycoo, 2018a) as The Environmental Protection and Tourism Improvement Fund Act, 40 2017 of British Virgin Islands shows (Smith, 2017). A lack of interaction between tourism and climate 41 change decision makers is a commonly identified issue (Becken, 2019; Mahadew and Appadoo, 2019; Scott 42 et al., 2019). A number of adaptation measures are recommended in the literature such as increasing climate 43 change research, education and institutional capacities; product and market diversification away from coastal 44 tourism to include terrestrial-based experiences and heritage tourism, and mainstreaming adaptation in 45 tourism policies and vice versa (e.g., to include appropriate planning guidelines for tourism development, 46 coastal setbacks and environmental impact assessments (Mycoo, 2018a; Becken et al., 2020) Thomas et al., 47 2020; van der Veeken et al., 2016). | Heritage | 2702 - 2702 |
| IPCC | IPCC_AR6_WGII_Full_Report | 24 25 In the Caribbean small islands such as Jamaica and St. Lucia, and also in the Pacific, barriers to 26 mainstreaming adaptation include competing development priorities, the absence of planning frameworks or 27 'undetected' overlaps in existing frameworks, serious governance flaws linked to the prevalence of 28 corruption and corrupt people in political and public life, and insufficient manpower and human resources, 29 linked to countries' financial capacity (Robinson, 2018b). In addition, the lack of strong governance 30 mechanisms for urban planning have contributed to urban sprawl and expansion that has increased the 31 number of informal settlements, which together with population growth are driving Caribbean small islands 32 to their limits (Enríquez-de-Salamanca, 2018; Mycoo, 2018a; Mycoo, 2018b). In the Pacific, only a few 33 countries have embedded climate change adaptation in existing legislation despite the overall regional 34 agreement to A New Song for Coastal Fisheries - Pathways to Change: the Noumea Strategy' to improve 35 coastal fisheries management in a changing climate (Gourlie et al., 2018). Many climate change specific 36 initiatives across small islands have a unidirectional focus on climate risks and shift limited resources away 37 from other important development objectives (Baldacchino, 2018). Local level plans are often overlooked: 38 for example, in Mauritius, local level climate adaptation plans are currently nearly non-existent while district 39 councils have rarely been successful in even accessing international adaptation finance (Williams et al., 40 2020). In Samoa, several national level programs on adaptation have had difficulties in engaging with the 41 local level even if the decision-making powers on actual land management sit within the communities 42 (McGinn and Solofa, 2020). | Heritage | 2704 - 2704 |
| IPCC | IPCC_AR6_WGII_Full_Report | 43 44 Adaptation governance is also complicated further by the multitude of stakeholders involved, with differing 45 agendas and priorities. In the Bahamas, private properties have significant say in how and what adaptation 46 measures they decide to pursue and are not well regulated, with the tourism sector in particular dominated 47 mainly by external investors (Petzold et al., 2018). Social organisations, such as the churches, that have 48 significant influence in many Oceanic countries, are engaging in climate change discussions and governance. | Heritage | 2704 - 2704 |

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| IPCC | IPCC_AR6_WGII_Full_Report | 23 24 Countries including the Seychelles and Maldives have developed national climate change plans that 25 recognize linkages to food security, health and disaster risk reduction, although these-face significant 26 resourcing issues when it comes to implementation (Techera, 2018). National level plans, such as National 27 Adaptation Plans of Action (NAPAs), increasingly could include local government engagement and have a 28 stronger focus on urban centres and adaptation (Mycoo, 2018a). Building codes act as supportive enablers 29 for adaptation governance: requiring more hurricane-resistant housing in the Caribbean, including incentives 30 for informal settlements to build in a more resilient manner, can achieve multiple development and 31 adaptation outcomes (Mycoo, 2018a). In Dominica, a Climate Resilience Executing Agency of Dominica 32 (CREAD) established in 2019, aims to enable stronger climate resilience by bringing all sectors and services 33 together for more effective coordination (Turner et al., 2020). Improvements in cross sectoral and cross 34 agency coordination are creating opportunities for improved disaster preparedness and resilience measures in 35 Vanuatu (Webb et al., 2015). A range of mechanisms also exists in the tourism industry: adaptation taxes 36 and improved building regulations could reduce risk drastically for example in the Caribbean region (Mycoo, 37 2018a). | Heritage | 2705 - 2705 |
| IPCC | IPCC_AR6_WGII_Full_Report | 12 Social networks also function as a source of informal microfinance where extended family members send 13 back remittances from overseas to their families and communities especially after disasters. In Samoa 14 Indigenous tourism operators receive remittances from overseas family members (Crichton and Esteban, 15 2018; Parsons et al., 2018), with similar processes observed among atoll communities in the Solomon 16 Islands (Birk and Rasmussen, 2014), Vanuatu (Handmer and Nalau, 2019) and Jamaica (Carby, 2017). | Heritage | 2707 - 2707 |
| IPCC | IPCC_AR6_WGII_Full_Report | 10 11 Workshops and training are seen as crucial at the local scale to build communities' capacity to take action 12 and to integrate climate change considerations to the broader development processes (Remling and 13 Veitayaki, 2016), although purely workshop-based short-term capacity building in adaptation has been 14 questioned (Conway and Mustelin, 2014; Lubell and Niles, 2019). More interactive community engagement 15 strategies could include "participatory three-Dimensional modelling (P3DM), participatory video, 16 development of photo journals, and civil society plans" (Beckford, 2018, p. 46) that enables broader 17 engagement. In Fiji, Laje Rotuma youth EcoCamps have been used to engage younger Fijians to understand 18 adaptation and increasing environmental stewardship with good outcomes (McNaught et al., 2014). In Palau, 19 Camp Ebiil provides a culturally-based platform for younger generations to learn about nature and culture in 20 an interactive camp (Singeo, 2011). Vanuatu's Volunteer Rainfall Observer Network in turn engages 21 volunteers to record their rainfall observations, demonstrating the use of IKLK that can be integrated with 22 contemporary weather forecasting (Chand et al., 2014). Likewise, initiatives such as ePOP Petites Ondes 23 Participatives aim to develop a citizen network to share environmental information (e.g., via minivideos on 24 smartphones). Across the Pacific, projects such as the European Union Pacific Technical Vocational 25 Education and Training on Sustainable Energy and Climate Change Adaptation Project (EU PacTVET), 26 have sought to increase capacity of Pacific islanders in disaster risk management and climate adaptation 27 (Hemstock et al., 2018). | Heritage | 2708 - 2708 |
| IPCC | IPCC_AR6_WGII_Full_Report | 42 43 The Caribbean Climate Online Risk and Adaptation tool has been developed to assist the tourism industry in 44 producing "climate-sensitive developments" (Mackay and Spencer, 2017,p. 55). Though some authors 45 conclude on the low climate awareness/understanding among small islanders (Middelbeek et al., 2014; 46 Betzold, 2015; Petzold et al., 2018), others indicate that many Caribbean islanders are acutely aware of past 47 storm events (i.e., social memory) and have a certain degree of self-reliance, which creates the capability to 48 multi-task and cope with limited resources (Petzold and Magnan, 2019). There is, however, a disconnect 49 between knowledge, attitudes and practices—knowledge sharing and learning need to be improved along 50 with the take-up of an evidence-based decision-making approach (Lashley and Warner, 2013; Petzold et al., 51 2018; Saxena et al., 2018). | Heritage | 2708 - 2708 |
| IPCC | IPCC_AR6_WGII_Full_Report | 52 53 15.6.5 Culture 54 55 Culture can be defined as "material and non-material symbols that express collective meaning" (Adger et al., 56 2014, p. 762) and includes worldviews and values, how individuals and communities relate to their 57 environment, and what they perceive to be at risk and in need of adaptation (McNaught et al., 2014; Nunn et ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 15 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 15-50 Total pages: 107 1 al., 2014; Remling and Veitayaki, 2016; Nunn et al., 2017bGranderson, 2017; Neef et al., 2018; Oakes, 2 2019). In small islands, culture plays an important role in individual and community decision-making on 3 adaptation both as an enabling factor and as a barrier (robust evidence, high agreement) (Nunn et al., 2017b; 4 Parsons et al., 2017; Neef et al., 2018; Piggott-McKellar et al., 2020). The concept of Vai Nui as the 5 interconnectedness of Pacific Islanders continues to support the collective agency to plan and undertake 6 adaptation efforts in the region (Hayward et al., 2019). In Samoa, the principles of Fa'asamoa (the Samoan 7 way of life) impacts on how decisions are made, including the role of the aiga (extended family) that is a 8 web of local, national and transnational kinship networks (Parsons et al., 2018). Traditional village council 9 structures and land stewardship enables an expanded range of coastal adaptation options in Samoa, including 10 potential relocation, but at the same time may limit participation of all social groups in adaptation decision 11 making (Crichton et al., 2020). In Dominica, in the aftermath of Hurricane Maria (2017), social capital in the 12 form of transboundary nearby island networks enabled some communities to recover faster from the disaster 13 including access to more livelihood opportunities and assets (Turner et al., 2020). | Heritage | 2708 - 2709 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 14  15 Yet, culture is often overlooked in adaptation policies and plans. For example, in the National   16 Communications of 16 SIDS, only one country (Cook Islands) reported adaptation actions that addressed   17 social issues, culture, and heritage (Robinson, 2018b). Externally-driven adaptation efforts in rural small-  18 island communities that exclude community priorities, ignore or undervalue IKLK, and are based on secular   19 western/global worldviews (Donner and Webber, 2014; Prance, 2015; McNamara et al., 2016; Nunn et al.,   20 2017b; Schwebel, 2017; Mallin, 2018; Nunn and McNamara, 2019; Piggott-McKellar et al., 2019b) are often   21 less successful (high agreement, medium evidence). The World Bank Kiribati Adaptation Program (KAP) for   22 example builds mainly on western knowledge and science despite consultations with the Kiribati   23 communities (Prance, 2015). Yet, in many contexts most land and knowledge is embedded in traditional   24 governance and culture while adaptation plans and decisions are made elsewhere on how that land should be   25 used and what knowledge is used (high agreement) (Nunn, 2013; Prance, 2015; Charan et al., 2017; Nalau et   26 al., 2018a; Parsons et al., 2018; McGinn and Solofa, 2020). | Heritage | 2709 - 2709 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 27  28 In Kiribati, communities often use different timescales to evaluate the need for adaptation. I-Kiribati   29 culture's core concept of time is short- and medium term (Prance, 2015), which should be considered in   30 adaptation policy and planning processes especially at the household and community level (Donner and   31 Webber, 2014). Key stakeholders, especially community leaders, should be included and empowered to help   32 design and sustain adaptation (Baldacchino, 2018; Weiler et al., 2018). Focusing on values-as-relations (e.g.,   33 island communities' relationship with the environment and each other) could diversify the values considered   34 in adaptation decision-making processes (Parsons and Nalau, 2019). Indeed, those Pacific islands with a   35 more island-centric approach to climate adaptation tend to have overall more successful adaptation policies   36 in place (Schwebel, 2017). | Heritage | 2709 - 2709 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 52  53 Decisions that are optimal for adaptation may not be acceptable in the wider development context within   54 which they operate. In the Pacific region, where 67% of infrastructure is located within 500 metres of   55 coastline and commercial, public and industrial infrastructure are particularly vulnerable due to the location   56 of urban centres (Kumar and Taylor, 2015). Yet the Parliamentary Complex in Samoa was redeveloped at   ACCEPTED VERSION   SUBJECT TO FINAL EDITS   FINAL DRAFT Chapter 15 IPCC WGII Sixth Assessment Report  Do Not Cite, Quote or Distribute 15-52 Total pages: 107  1 the original site due to cultural and historical factors despite strong evidence of the need to relocate (Hay et   2 al., 2019b). | Heritage | 2710 - 2711 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 9  10 Tourism system transitions can enable the sector to contribute to climate resilient development pathways   11 through managing climate risks and improving ecological, economic and social outcomes for small islands  12 (medium evidence, high agreement) (Loehr, 2019; Mahadew and Appadoo, 2019; Loehr et al., 2020; Sheller,   13 2020). | Heritage | 2711 - 2711 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 29  30 Early research on the response to COVID-19 indicates that existing disaster response mechanisms in the   31 Caribbean islands have assisted in rapid responses to COVID-19 (Hambleton et al., 2020). Many small   32 islands are highly dependent on tourism for their economies and are facing worsening crises associated with   33 climate-related disasters and more recently COVID-19 disruptions of travel (Sheller, 2020). The adaptive   34 capacity and innovations demonstrated by SIDS during COVID-19, moving beyond dependence on   35 'extractive' international tourism, demonstrate the potential benefits of diversified and sustainable   36 economies (and ecologies) for the enhanced resilience of both human and ecological communities (Sheller,   37 2020). | Heritage | 2711 - 2711 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 18  19 Observed changes – including increases in air and ocean temperatures, increases in storm surges, heavy   20 rainfall events, and possibly more intense tropical cyclones - are already reducing the number and quality of   21 ecosystem services, thereby causing the disruption of human livelihoods, damage to buildings and   22 infrastructure, and loss of economic activities and cultural heritage on small islands. Widespread observed   23 impacts include severe coral reef bleaching events, such as that associated with the 2015–16 El Niño season,   24 the most damaging on record worldwide. Additionally, the 2017 Atlantic hurricane season was unusually   25 characterised by sequential severe tropical cyclones that resulted in widespread cyclone-induced damage to   26 ecosystems from the very interior of small islands to those of the ocean waters that surround them as well as   27 damage to human settlements and economic activities within the whole Caribbean region. Although   28 knowledge is limited regarding long term increases in tropical cyclone intensity, studies have shown that   29 heavy rainfall and intense wind speed of individual tropical cyclones were increased by climate change. The   30 combination of various climate events, such as tropical cyclones, extreme ocean waves, and El Niño or La   31 Niña phases, with sea-level rise causes increased coastal flooding, especially on low-lying atoll islands of the   32 Indian and Pacific Oceans. | Heritage | 2712 - 2712 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 47  48 The intensity and timing of such impacts will be more severe under high warming futures compared to low   49 warming futures accompanied by ambitious adaptation. Tailored, desirable and locally owned adaptation   50 responses that incorporate both short- and long-term time horizons would certainly help to reduce future   51 risks to nature and human life in small islands. Among the short-term measures frequently employed to   52 address sea-level rise and flooding are seawalls. Long-term measures include ecosystem-based adaptation   53 such as mangrove replanting, relocation of coastal villages to upland sites, creation of elevated land through   54 reclamation, revised building codes as part of a broader disaster risk reduction strategy, shifting to alternative   55 livelihoods and changes in farming and fishing practices. | Heritage | 2712 - 2712 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 19 20 Coastal livelihoods in particular are already impacted by climate impacts. Coastal fishers have adapted to 21 these changes in environmental conditions by diversifying livelihoods, expanding aquaculture production, 22 considering weather insurance, building social networks to cope with reduced catches and availability during 23 extreme storms, switching fishing grounds, and changing target species. Similarly, farmers have diversified 24 livelihoods to more cash- and service-based activities such as tourism, changed plant species that thrive 25 better in altered conditions, and shifted planting seasons according to changes in climate. | Heritage | 2713 - 2713 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 38 Along small-island coasts, anticipatory adaptation typically involves recognising that sea level will continue 39 rising and that problems currently experienced will be amplified in the future. One strategy for anticipatory 40 adaptation in response to sea level rise and flooding is relocation, which is the movement of coastal 41 communities away from vulnerable (coastal-fringe) locations to sites that are further inland. . Coastal setback 42 policies have been applied to hotels in some islands such as Barbados. In coastal locations where the risks of 43 rising sea level, flooding and erosion are very high and cannot effectively be reduced, 'retreat' from the 44 shoreline is the only way to eliminate or reduce such risks. | Heritage | 2713 - 2713 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 12 13 Ecosystem-based adaptation can be a low-cost anticipatory adaptation measure that is often used in small 14 islands. It is referred to as a 'no-regret' or 'low-regret' strategy because it is low-costing, brings co-benefits 15 and requires less maintenance in contrast to hard engineering structures. Ecosystem-based adaptation is used 16 at different scales and in different sectors such as to protect fisheries, farming and tourism assets, and 17 integrates various stakeholders from national to local governments and non-governmental agencies. Many 18 islands have implemented ecosystem-based adaptation such as watershed management, mangrove replanting 19 and other nature-based solutions to strengthen coastal foreshore areas that are subjected to coastal erosion 20 and flooding caused by sea level rise and changing rainfall patterns. For example, mangroves have been 21 planted on several cays in Belize and pandanus trees have been planted near the coastlines of the Marshall 22 Islands. Agroforestry is another example of ecosystem-based adaptation. Planting trees and shrubs in 23 combination with crops has been used to increase resilience of crops to droughts or excessive rainfall run- 24 off. Case studies show that people living on islands benefit even further from using ecosystem-based 25 adaptation. Their health improves as well as their food and water supply, while risks of disasters caused by 26 extreme events are reduced. | Heritage | 2714 - 2714 |
| IPCC | IPCC_AR6_WGII_Full_ Report | Impacts include inundation of settlements, infrastructure, and tourism facilities as well as coastal erosion. These waves can propagate to and influence reef islands in equatorial areas not usually exposed to high energy waves. | Heritage | 2720 - 2720 |
| IPCC | IPCC_AR6_WGII_Full_ Report | These extraordinary sargassum 'blooms' have resulted in mass deposition of seaweed on beaches throughout the Lesser Antilles, with damage to coastal habitats, mortality of seagrass beds and associated corals, as well as consequences for fisheries and tourism. This recent phenomenon has been linked to climate change as well as the possible influence of nutrients from Amazon River floods and/or Sahara dust. | Heritage | 2721 - 2721 |
| IPCC | IPCC_AR6_WGII_Full_ Report | Of the range of bacterial, fungal and protozoan diseases known to affect stony corals, many have explicit links to temperature. Global projections suggest that disease is as likely to cause coral mortality as bleaching in the coming decades at many localities, with effects occurring earlier at sites in the Caribbean compared to the Pacific and Indian oceans. Model hindcasts suggest that climate�driven changes in sea surface temperature, as well as extreme heatwave events have all played a significant role in the spread of white-band disease throughout the Caribbean. | Heritage | 2722 - 2722 |
| IPCC | IPCC_AR6_WGII_Full_ Report | Key Risks Risk-oriented adaptation options Evidence and agreement Implementation Key enablers Reduction of exposure and vulnerability Co-benefits Disbenefits KR1. Loss of marine and coastal biodiversity and ecosystem services EbA measures (15.4.4) MPAs; paired terrestrial and MPAs Medium evidence, low agreement with regard to climate change adaptation and benefits Widespread across small islands, with climate resilience being a target of some MPAs Strong governance and sufficient financial resources Reduces the ecosystem exposure to human disturbances, increasing their resistance and resilience to climate events For biodiversity, food supply, economics, human health and well�being Active restoration of coastal and marine ecosystems Limited evidence, low agreement with regard to long-term success Mostly small�scale: replanting of mangroves, seagrasses and beach vegetation; transplantation of corals; beach nourishment Funding: adaptation taxes and levies imposed on tourism; blue bonds; public�private partnerships Reduces the vulnerability of natural ecosystems by increasing their resilience Improved water quality; reduction in coastal erosion and flood risks; economic benefits Hard protection (15.5.1) Hard structures designed to enhance marine biodiversity Medium evidence, medium agreement Artificial reefs Funding: adaptation and environmental taxes and levies, with limited evidence of direct reinvestment in conservation and management Uncertainty on reduction of exposure and vulnerability of marine ecosystems; reduces the exposure of population and infrastructure to coastal risks For food supply, economies (tourism), human health and well�being Diversifying livelihoods (15.5.6) Diversifying fisheries livelihoods (e.g. to aquaculture and tourism), Limited to medium evidence, Examples in the Caribbean region and in the Improved governance and cooperation (e.g. | Heritage | 2724 - 2724 |

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| IPCC | IPCC_AR6_WGII_Full_Report | Maldives) Financial Yes Health; economic (reduced dependence on public supply) Energy intensive (carbon footprint) ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 15 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 15-69 Total pages: 107 Reforestation (15.5.4) Medium evidence, high agreement Examples reported in the Caribbean and Pacific (e.g. Fiji, Papua New Guinea) Governance - whole�of-island approaches foster integrated management practices in small islands Yes, through supporting wetland�oriented tourism Economic (agroforestry); biodiversity (watershed restoration); food security; disaster risk reduction Dependent on mode of implementation. | Heritage | 2727 - 2728 |
| IPCC | IPCC_AR6_WGII_Full_Report | Hulhumale', Maldives) Technological, financial, institutional, sociocultural, high potential in urban (compared to rural) areas Reduces population exposure where high standard as in Hulhumale', Maldives Offers new land for economic development, generates revenues through sale or lease of land in urban areas Widespread ecosystem destruction, increased negative ACCEPTED impacts of SLR VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 15 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 15-70 Total pages: 107 growth in the Maldives) Migration including planned resettlement (15.5.3) Limited evidence, low agreement with regard to climate change adaptation Village-scale planned resettlement supported by government policy/legislation in the Pacific Participatory inclusion of all social groups; financial (for small and remote communities); social-cultural connections; strong governance frameworks; enabling legislation; land availability or ownership; conditions in receiving locations; technical support Reduced exposure locally; has created new vulnerabilities at some locations by bearing significant economic cost, impacting social capital and reducing access to services New livelihood opportunities Loss of cultural heritage, impacts on receiving communities EbA measures (15.4.4) Medium agreement, medium evidence Increasingly experienced; includes artificial reefs, beach nourishment and vegetation (including mangrove) restoration Environmental/physical conditions; social acceptability; technical capacities (enhanced by external support); funding; inclusion in national adaptation policies Limited evidence to date Biodiversity strengthening; increased food supply; increased human health and well-being KR6. Health degradation Increasing public awareness of health risks associated with climate change; providing training to health sector staff; improving reliability and safety of water storage practices (15.6.2) Limited evidence Few examples Financial and human resources to implement options; early warning and response systems; integrating climate services into health decision-making systems; public uptake and buy in; improving health data collection systems Primarily reduces vulnerability Increased water security ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 15 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 15-71 Total pages: 107 KR7. | Heritage | 2728 - 2730 |
| IPCC | IPCC_AR6_WGII_Full_Report | Limited examples of successful livestock husbandry only in Jamaica Investments in farm inputs Adaptive finance/education (15.5.6) Limited evidence, medium agreement Limited (e.g. in Puerto Rico, women engage in new Tourism income; investment in education and capacity building; Yes, reduces risk and avoids negative Generates opportunities (e.g. | Heritage | 2730 - 2730 |
| IPCC | IPCC_AR6_WGII_Full_Report | for wetland tourism) ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 15 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 15-72 Total pages: 107 commercial enterprises that do not rely on traditional coffee supply chains or government assistance) working with nature and EbA knock-on effects Product/Market diversification (15.5.6) Diversity of crops, gardening in different areas, storage and preservation of foodstuffs, engagement of women in new commercial enterprises Medium evidence, high agreement Examples in the Caribbean region and Pacific Availability of crops and land, new markets Reduces vulnerability to tropical cyclones in Fiji and Vanuatu; new markets in Puerto Rico Increases food security and improves nutrition; increases income security Adaptation in tourism policies (15.5.6) Limited evidence, high agreement Limited (e.g. in the British Virgin Islands, policies like adaptation taxes and levies imposed on tourism can provide funding for adaptation measures) Tourism regulations and policies that mainstream climate change adaptations; taxes and levies imposed on tourism Limited evidence in reducing vulnerability KR8. Loss of cultural resources and heritage Integrating Indigenous Knowledge and local knowledge (IKLK) with western science to provide integrated approaches to climate change (15.6.5) Medium evidence, high agreement Reported in the Pacific and Caribbean Use of IKLK for preparing for disasters and understanding environmental change; social networks in sharing information and helping others; ecotheology increasing people's awareness of the environment Yes, can reduce vulnerability when IK LK supports robust adaptation; No, can increase vulnerability if IKLK no longer provides Can increase climate change information and its understanding in communities, and increase culturally appropriate climate adaptation Reports from Vanuatu indicates that IK LK are at times inaccurate (eg seasonal calendars, biophysical weather indicators) due to climate ACCEPTED change VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 15 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 15-73 Total pages: 107 accurate information Hard protection (15.5.5.1) Medium agreement, limited evidence with regard to climate change adaptation and success Widespread in protecting cultural sites and villages in both urban and rural areas of the Caribbean, Pacific and Indian Oceans External funding; socio-cultural (generally meets the preference of the population); political�institutional (e.g. | Heritage | 2730 - 2732 |

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| Organisation | Document | Quotation Content | Codes | Page |
| --- | --- | --- | --- | --- |
| IPCC | IPCC_AR6_WGII_Full_ Report | (2019) Trotman et al. (2018) SPREP (2016a) Economy and Finance Economic diversification and shifting to CRDPs Tourism system transitions/cooperation from tourism sector Loehr (2019); Mahadew and Appadoo (2019); Loehr et al. (2020); Sheller (2020) Finance models for adaptation Innovative financing models that enable adaptation (e.g., Seychelles) Parametric fisheries insurance products to increase fishery resilience funded by Caribbean Catastrophe Risk Insurance Facility (Grenada and Saint Lucia) Rambarran (2018) CCRIF (2019) Transregional trade agreements/associated pressure Revised socio-political arrangements for better fisheries management (Solomon Islands) Keen et al. (2018) Economic viability via revenue from sale of new land Maldives land raising on Hulhumale "Safe island development programme" after 2004 Indian Ocean Tsunami in the Maldives Bisaro et al. (2019) Shaig (2008) Government subsidies Tuamotu's government subsidy of raised houses Magnan et al. (2018) Co-investments and cooperation between agencies (donors, governments) Tuvalu use of beach nourishment in collaboration with JICA Onaka et al. (2017) Diversification of livelihoods as basis for economic activity Coastal fishers' diversification of livelihoods into the tourism sector (Vanuatu and Madagascar) Blair and Momtaz (2018) ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 15 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 15-75 Total pages: 107 Fishermen varying fishing practices and locations depending on environmental conditions (e.g., Dominican Republic) Karlsson and McLean (2020) Governance Changed governance arrangements resulting in improved coordination Improved governance arrangements: Cross�sectoral and cross-agency coordination (e. g. | Heritage | 2733 - 2734 |
| IPCC | IPCC_AR6_WGII_Full_ Report | A paucity of research exists currently on the vulnerability of island ecosystem services to climate change (Balzan et al., 2018). While there is rich scientific evidence on the pressures of habitat loss and degradation, impacts of natural hazards and invasive species, far less is known about the interactions of these factors with adaptive capacity and livelihood conditions on islands. In small island contexts, there is a specific need for assessing the effectiveness and cost of ecosystem - and community-based solutions where the latter have been implemented (Filho et al., 2020). The design of generic assessment methods and tools is required to allow for comparative analyses that will, in turn, provide useful guidance for the promotion of context�specific adaptation strategies (Blair and Momtaz, 2018). For many of the small islands, especially SIDS, the economic valuation of marine and coastal ecosystem services – coastal protection, fisheries, tourism - is of great importance, as well as the subsequent losses in these sectors and related livelihoods due to climate change impacts (Waite et al., 2014; Schuhmann and Mahon, 2015; World Bank, 2016; Layne, 2017; Duijndam et al., 2020). There are few integrated modelling studies to inform future habitability of differentiated small island types and how these models can inform decision support processes for ridge to reef stewardship (Povak et al., 2020). Existing studies (Rasmussen et al., 2018) have progressed knowledge since AR5, but island-specific analyses are required to robustly estimate the future ability of land to support life and livelihoods, taking into account multiple climate-drivers, future population exposure, and adaptation responses. | Heritage | 2735 - 2735 |

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| Organisation | Document | Quotation Content | Codes | Page |
|---|---|---|---|---|
| IPCC | IPCC_AR6_WGII_Full_Report | with high exposure/vulnerability, low 57 adaptation, or both (high confidence). Under these conditions there would be severe and pervasive risks to ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 16 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 16-6 Total pages: 173 1 critical infrastructure and to human health from heat-related mortality (high confidence), to low-lying coastal 2 areas, aggregate economic output, and livelihoods (all medium confidence), of armed conflict (low 3 confidence), and to various aspects of food security (with different levels of confidence). Severe risks 4 interact through cascading effects, potentially causing amplification of RKRs over the course of this century 5 (low evidence, high agreement). {16.5.2.3, 16.5.2.4, 16.5.4, Figure 16.10} 6 For some RKRs, potentially global and systemically pervasive risks would become severe even with 7 medium to low warming (i.e. 1.5-2°C) if exposure/vulnerability is high and/or adaptation is low 8 (medium to high confidence). Under these conditions there would be severe and pervasive risks associated 9 with water scarcity and water-related disasters (high confidence), poverty, involuntary mobility, and insular 10 ecosystems and biodiversity hotspots (all medium confidence). {16.5.2.3, 16.5.2.4} 11 12 All potentially severe risks that apply to particular sectors or groups of people at more specific 13 regional and local levels require high exposure/vulnerability or low adaptation (or both), but do not 14 necessarily require high warming (high confidence). Under these conditions there would be severe, 15 specific risks to low-lying coastal systems, to people and economies from critical infrastructure disruption, 16 economic output in developing countries, livelihoods in climate-sensitive sectors, waterborne diseases 17 especially in children in low- and middle-income countries, water-related impacts on traditional ways of life, 18 and involuntary mobility for example in small islands and low-lying coastal areas (medium to high 19 confidence). {16.5.2.3, 16.5.2.4} 20 21 Some severe impacts are already occurring (high confidence) and will occur in many more systems 22 before mid-century (medium confidence). Tropical and polar low-lying coastal human communities are 23 experiencing severe impacts today (high confidence), and abrupt ecological changes resulting from mass 24 population-level mortality are already observed following climate extreme events. Some systems will 25 experience severe risks before the end of the century (medium confidence), for example critical infrastructure 26 affected by extreme events (medium confidence). Food security for millions of people, particularly low- 27 income populations, also faces significant risks with moderate to high warming or high vulnerability, with a 28 growing challenge by 2050 in terms of providing nutritious and affordable diets (high confidence). {16.5.2.3, 29 16.5.3} 30 31 In specific systems already marked by high exposure and vulnerability, high adaptation efforts will 32 not be sufficient to prevent severe risks from occurring under high warming (low evidence, medium 33 agreement). This is particularly the case for some ecosystems and water-related risks (from water scarcity 34 and to indigenous and traditional cultures and ways of life). {16.5.2.3, 16.5.2.4, 16.5.3} 35 36 Interconnectedness and globalization establish pathways for the transmission of climate-related risks 37 across sectors and borders, for instance through trade, finance, food, and ecosystems (high 38 confidence). Examples include semiconductors, global investments, major food crops like wheat, maize and 39 soybean, and transboundary fish stocks. There are knowledge gaps on the need for, effectiveness of, and 40 limits to adaptation to such interregional risks {Cross-Chapter Box INTERREG in this Chapter} 41 42 Key risks increase the challenges in achieving global sustainability goals (high confidence). The greatest 43 challenges will be from risks to water (RKR-G), living standards (RKR-D), coastal socio-ecological systems 44 (RKR-A) and peace and human mobility (RKR-H). The most relevant goals are Zero hunger (SDG2), 45 Sustainable cities and communities (SDG11), Life below water (SDG14), Decent work and economic 46 growth (SDG8), and No poverty (SDG1). Priority areas for regions are indicated by the intersection of 47 hazards, risks and challenges, where, in the near term, challenges to SDGs indicate probable systemic 48 vulnerabilities and issues in responding to climatic hazards. (high confidence) {16.6.1} 49 50 The scale and nature of climate risks is partly determined by the responses to climate change, not only in 51 how they reduce risk, but also how they may create other risks (sometimes inadvertently, and sometimes to 52 others | Heritage | 2771 - 2772 |
| IPCC | IPCC_AR6_WGII_Full_Report | 11 12 RFC1, RFC2 and RFC5 include risks that are irreversible, such as species extinction, coral reef degradation, 13 loss of cultural heritage, or loss of a small island due to sea level rise. Once such risks materialise, as is 14 expected at very high risk levels, the impacts would persist even if global temperatures would subsequently 15 decline to levels associated with lower levels of risk in an 'overshooting' scenario (high confidence). | Heritage | 2774 - 2774 |
| IPCC | IPCC_AR6_WGII_Full_Report | 12 13 16.2.3.7 Vector-borne Diseases 14 15 Vector-borne diseases constitute a large burden of infectious diseases worldwide and are highly sensitive to 16 fluctuations of weather conditions including extreme events. Thus, both extreme rainfall and droughts have 17 increased infections (high confidence, see documentation of cases in 'Other societal impacts - Vector-borne 18 diseases', Table SM16.23). For example, in Sudan, anomalous high rainfall increased Anopheles mosquito 19 breeding sites, leading to malaria outbreaks (Elsanousi et al., 2018) while in Barbados and Brazil, drought 20 conditions in urban areas have enhanced dengue incidence due to changes in water storage behaviour 21 creating breeding sites for Aedes mosquitoes around human dwellings (Lowe et al., 2018; Lowe et al., 22 2021)). In the Caribbean and Pacific island nations, weather extremes, such as storms and flooding have led 23 to outbreaks of dengue due to disruption to water and sanitation services, leading to increased exposure to 24 Aedes mosquito breeding sites (Descloux et al., 2012; Sharp et al., 2014; Uwishema et al., 2021). In South 25 and Central America, and Asia, dengue incidence has been shown to sensitive to variations in temperature 26 and the monsoon season in addition to variations induced by urbanization and population mobility (high 27 confidence (South and Central America); medium confidence (Asia); see 'Other societal impacts - Vector- 28 borne diseases', Table SM16.23). | Heritage | 2787 - 2787 |
| IPCC | IPCC_AR6_WGII_Full_Report | 22 Engagement by sub-national governments in adaptation is more frequently documented in Europe and North 23 America (Craft and Howlett, 2013; Craft et al., 2013; Bauer and Steurer, 2014; Lesnikowski et al., 2015; Shi 24 et al., 2015; Austin et al., 2016). Reporting of private sector engagement is generally low. Civil society 25 participation in adaptations is reported across all regions. Consistent with this, local governments are also 26 widely reported in documented adaptation responses, particularly where municipal jurisdiction is high, 27 including cities, infrastructure, water, and sanitation. | Heritage | 2794 - 2794 |

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| IPCC | IPCC_AR6_WGII_Full_Report | 30 31 The mix of adaptation response types differs across regions and sectors. Technological and infrastructural 32 responses are widely reported in Europe, and globally in the context of cities and water and sanitation (Mees, 33 2017; Hintz et al., 2018). Responses to flood risk in Europe include the use of flood and climate resistant 34 building materials, large scale flood management, and water storage and irrigation systems (van Hooff et al., 35 2015; Mees, 2017). Technological and infrastructural responses are also documented to some extent in 36 agriculture, including for example breeding more climate resilient crops, precision farming and other high- 37 tech solutions such as genetic modification (Makhado et al., 2014; Fisher et al., 2015; Costantini et al., 2020; 38 Fraga et al., 2021; Grusson et al., 2021; Naulleau et al., 2021). While less common, institutional responses 39 are more prominent in North America and Australasia as compared to other regions, and include zoning 40 regulations, new building codes, new insurance schemes, and coordination mechanisms (Craft and Howlett, 41 2013; Craft et al., 2013; Parry, 2014; Ford et al., 2015b; Beiler et al., 2016; Lesnikowski et al., 2016; Labbe 42 et al., 2017; Sterle and Singletary, 2017; Hu et al., 2018; Conevska et al., 2019). Institutional adaptations are 43 more frequently reported in cites than other sectors. Institutional adaptation may be particularly subject to 44 reporting bias, however, with many institutional responses likely to be reported in the grey literature (see 45 Chapter 17). Nature-based solutions are less frequently reported, except in Africa, where they are relatively 46 well-documented, and in the content of terrestrial systems where reports included species regeneration ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 16 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 16-30 Total pages: 173 1 projects, wind breaks, erosion control, reforestation, and riparian zone management (Munji et al., 2014; 2 Partey et al., 2017; Muthee et al., 2018). | Heritage | 2795 - 2796 |
| IPCC | IPCC_AR6_WGII_Full_Report | (2019) Storage of large quantities of water in the home Water rendered unsafe for drinking due contamination by fecal coliforms in Zimbabwe; drought-induced changes in water harvesting and storage increased breeding sites for mosquitoes (Australia); Water storage facilities and tanks provided ideal breeding conditions for mosquitoes and flies bringing both vectors and diseases closer to people (Ethiopia). | Heritage | 2801 - 2801 |
| IPCC | IPCC_AR6_WGII_Full_Report | (2014);Wiederkehr et al. (2018); Yegbemey et al. (2017); Yila and Resurreccion (2013); Nizami et al. (2019); Mersha and Van Laerhoven (2016); Ojha et al. (2014); Radel et al. (2018); Gioli et al. (2014); Hooli (2016); Koubi et al. (2016) ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 16 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 16-37 Total pages: 173 Certain autonomous, forced, and planned relocation Temporary resettlement (India) Expansion of informal settlements in cities (Solomon Islands); relocation to areas prone to landslide and soil erosion or insufficient housing (Fiji); disproportionate burden on vulnerable communities (China); temporary relocation created gender inequality associated with minimal privacy; poor access to private toilets; sexual harassment; reduced sleep; insufficient or food rationing; exploitation and abuse of children (India); inadequate funding and governance mechanism for community-based relocation caused loss of culture, economic decline and health concerns (Alaska); relocation of supply chain to reduce exposure to climate change resulted in adverse outcomes for communities along the supply chain. | Heritage | 2802 - 2803 |
| IPCC | IPCC_AR6_WGII_Full_Report | (2019) Return to traditional farming practices Mitigation, especially carbon sequestration Pienkowski and Zbaraszewski (2019) Place-specific practices & innovations: animal cross-breeding; direct crop seeding; site�specific nutrient management; irrigation innovations; use of riparian buffer strips; Mitigation, especially carbon sequestration; improved crop yields; food security Sushant (2013); Balaji et al. (2015); Helling et al. (2015); Jorgensen and Termansen (2016); Sen and Bond (2017); Wilkes et al. | Heritage | 2803 - 2803 |
| IPCC | IPCC_AR6_WGII_Full_Report | (2020) ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 16 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 16-38 Total pages: 173 use of green winter land; rice-rice system Land and water management Agroforestry Mitigation, especially carbon sequestration; biodiversity and ecosystem conservation; improved food security; plant species diversification; diversification of household livelihoods; improved household incomes; improved access to forage material; energy access and reduced fuel wood gathering time and distance for women; soil and water conservation; aesthetic improvements in landscapes Holler (2014); Suckall et al. (2015); Sharma et al. (2016); Nyasimi et al. (2017); Pandey et al. (2017); Schembergue et al. (2017); Ticktin et al. (2018); Debray et al. (2019); Jezeer et al. (2019); Krishnamurthy et al. (2019); Nyantakyi-Frimpong et al. (2019); Tschora and Cherubini (2020) Afforestation and reforestation programs; Forest management practices (e.g., tree thinning) Mitigation, especially carbon sequestration; biodiversity and ecosystem conservation; new employment opportunities; diversification of household livelihoods; increased household incomes; improved access to fuel wood; harvesting opportunities from enclosures Holler (2014); Etongo et al. (2015); Diederichs and Roberts (2016); Acevedo�Osorio et al. (2017); Nyasimi et al. (2017); Krishnamurthy et al. (2019); Rahman et al. | Heritage | 2803 - 2804 |

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| Organisation | Document | Quotation Content | Codes | Page |
|---|---|---|---|---|
| IPCC | IPCC_AR6_WGII_Full_ Report | 25 26 16.4.2.1 Small Island Developing States (SIDS) 27 28 An expanding volume of empirical research highlights existing adaptation constraints that may lead to soft 29 limits in SIDS. Investigation of national communications among 19 SIDS found that financial constraints, 30 institutional challenges and poor resource endowments were the most-frequently reported as inhibiting 31 adaptation for a range of climate impacts (Robinson, 2018b). Governance, financial and information 32 constraints such as unclear property rights and lack of donor flexibility have led to hasty implementation of 33 adaptation projects in Kiribati, whereas in Vanuatu and the Solomon Islands, limited awareness of rural 34 adaptation needs and weak linkages between central governance and local communities have resulted in an 35 urban bias in resource allocation (Kuruppu and Willie, 2015). Limited availability and use of information 36 and technology also present constraints to adaptation – many SIDS suffer from lack of data and established 37 routines to identify loss and damage, and the combination of poor monitoring of slow-onset changes and 38 influence of non-climatic determinants of observed impacts challenges attribution (Thomas and Benjamin, 39 2018). The fact that climate information is often available only in the English language represents another 40 common constraint for island communities (Betzold, 2015). Although indigenous and local knowledge 41 systems can provide important experience-based input to adaptation policies (Miyan et al., 2017), socio- 42 cultural values and traditions such as attachment to place, religious beliefs and traditions can also constrain 43 adaptation in island communities, particularly for more transformational forms of adaptation (Ha'apio et al., 44 2018; Oakes, 2019). | Heritage | 2812 - 2812 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 12 13 Residual risks for SIDS include loss of marine and terrestrial biodiversity and ecosystem services, increased 14 food and water insecurity, destruction of settlements and infrastructure, loss of cultural resources and 15 heritage, collapse of economies and livelihoods and reduced habitability of islands (Section 3.5.1, Section 16 15.3). | Heritage | 2813 - 2813 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 47 48 Residual risks associated with livelihoods in Africa include poorer households becoming trapped in cycles of 49 poverty (Section 9.9.3), increased rates of rural-urban migration (Section 9.8.4), decline of traditional 50 livelihoods such as in agriculture (Section 9.9.3, Section 9.11.3.1) and fisheries (Section 9.11.1.2) and loss of 51 traditional practices and cultural heritage (Section 9.9.2). | Heritage | 2814 - 2814 |
| IPCC | IPCC_AR6_WGII_Full_ Report | Actor/system at risk Adaptation limits Residual risks Terrestrial species in islands at risk to loss of habitat Hard: autonomous adaptation unable to overcome loss of habitat and lack of physical space (***) (Box CCP1.1) Biodiversity decline, local extinctions, half of all species currently considered to be at risk of extinction occur on islands (Box CCP 1.1) Terrestrial species across Africa at risk to habitat changes Hard: beyond 2°C many species will lack suitable climate conditions by 2100 despite migration and dispersal (***) (9.6.4.1) 9% of species face complete range loss (*) mountain-top endemics and species at poleward boundaries of African continent at risk of range loss due to disappearing cold climates (***) (9.6.4.1) African aquatic organisms at risk to habitat changes Hard: thermal changes above optimal physiological limits will reduce available habitats (9.6.2.4) Greater risks of loss of endemic fish species than generalist fish species (9.6.2.4) African coastal and marine ecosystems at risk to habitat changes Hard: at 2°C bleaching of east African coral reefs (***) (9.6.2.3) Over 90% of east African coral reefs destroyed at 2C (***) (9.6.2.3) Coral reefs at risk to oceanic changes Hard: coral restoration and management no longer effective after 2°C (***), enhanced coal and reef shading no longer effective after 3°C (**) (Figure 3.23) Loss of more than 80% of healthy coral cover, loss of livelihoods dependent on coral reefs (***) (Figure 3.23, Table 8.7) Cold-adapted species whose habitats are restricted to polar and high mountaintop areas at risk to loss of climate space Hard: evolutionary responses unable to keep pace with the rate of climate change and degraded state of ecosystems (2.6.1, CCP 1.2.4.2) Species extinctions in the case of species losing its climate space entirely on a regional or global scale (2.6.1, CCP 1.2.4.2) Ecosystems in North America at risk to multiple climate hazards Soft: governance constraints hinder implementation of adaptation strategies Hard: some species unable to adapt (Table 14.8) - Ecosystems and species at risk to multiple climate hazards Soft: financial and knowledge constraints lead to limits for interventionist approaches such as translocation of species or ecosystem restoration Hard: some habitats unable to be effectively restored (2.6.6) Species extinctions and changes, irreversible major biome shifts (2.6.6) Coastal settlements in Australia and New Zealand at risk to sea level rise Soft and hard: limits in the efficacy of coastal protection and accommodation approaches as sea levels rise and extreme events intensify (Box 11.5) With 1-1.1m of sea level rise, value of coastal urban infrastructure at risk in Australia is A$164 to >226 billion while in NZ it is NZ$43 billion. Sea level rise will also result in significant cultural and archaeological sites disturbed and increasing flood risk and water insecurity with health and well-being impacts on Australia's small northern islands (Box 11.5) ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 16 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 16-51 Total pages: 173 Human settlements in coastal areas in the 1 in 100 year floodplain at risk to coastal flooding Soft: socio-economic, institutional and financial constraints may lead to soft limits well in advance of technical limits of hard engineering measures (CCP 2.3.2, 2.3.4) Hard: Nature based measures (e.g. | Heritage | 2816 - 2817 |

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|---|---|---|---|---|
| IPCC | IPCC_AR6_WGII_Full_Report | US$12,739 billion in assets at risk by 2100 (CCP 2.2.1) Communities in small islands at risk to freshwater shortages Hard: domestic freshwater resources unable to recover from increased drought, sea level rise and decreased precipitation by 2030 (RCP8.5+ ice-sheet collapse), 2040 (RCP8.5) or 2060 (RCP4.5) (Box 4.2, 4.7.2) Migration of communities due to water shortages with impacts on well-being, community cohesion, livelihoods and people-land relationships (Box 4.2) Communities in North America at risk to poor water quality Soft: financial and technological constraints lead to limits in ability to treat water for harmful algal blooms. (Table 14.8) Communities in Western and Central Europe at risk to water shortages Hard: at 3°C, geophysical and technological limits reached in Southern Europe (13.10.3.3) At 3°C, two thirds of the population of Southern Europe at risk to water security with significant economic losses in water and energy dependent sectors (**) (13.2.2, 13.6, 13.10.2.3) Communities in Central and South America at risk to water shortages Soft: improved water management as an adaptation strategy unable to overcome lack of trust and stakeholder flexibility, unequal power relations and reduced social learning. (12.5.3.4) Increasing competition and conflict associated with high economic losses (**); glacier shrinkage leading to loss of related livelihoods and cultural values (12.5.3.1, Table 8.7) Agricultural production in Europe at risk to heat and drought Soft: above 3°C, unavailability of water will limit irrigation as an adaptation response (***) (13.5.1, 13.10.2.2) At 3-4°C, yield losses for maize may reach up to 50% (**) (13.5.1, 13.10.2.2) Crops at risk to temperature increase Soft: socio-economic and political constraints limit uptake of climate-resilient crops (5.4.4.3) Hard: after 2°C, cultivar changes unable to offset global production losses (5.4.4.1) Costs of adaptation and residual damages are US$63 billion at 1.5°C. US$80 billion at 2°C and US$128 billion at 3°C, with greater risks and damages in tropical and arid regions (5.4.4.1) Human health in Europe at risk to heat Soft: many adaptation measures will not be able to fully mitigate overheating in buildings with high levels of global warming (***) (13.6.2.3) Hard: above 3°C, people and health systems unable to adapt (***) (13.6.2.3, 13.7.2, 13.7.4, 13.10.2.1, 13.8) At 1.5°C, 30,000 annual deaths due to extreme heat with up to 90,000 annual deaths at 3C in 2100 (***) (13.7.1) At 3°C, thermal comfort hours during summer will decrease by as much as 74% in locations in southern Europe (***) (13.6.1.5) Human health at risk to heat Soft: socio-economic constraints limit adaptation responses to extreme heat (7.4.2.6, Table 8.7) Globally the impact of projected climate change on temperature�related mortality is expected to be a net increase under RCP4.5 to RCP8.5, even with adaptation, particularly for regions with warm climates (****) (7.3.1, Table 8.7) South Asian settlements at risk to coastal flooding, drought, sea level rise and heatwaves Soft and hard: At 4.5ºC, maximum temperature is expected to exceed survivability threshold across most of South Asia, particularly relevant for outdoor work (*) (Table 10.6) At RCP4.5, 25-50% of population affected; at RCP8.5 more than 50% of population affected. At 4.5ºC of warming, increase in heat-related deaths of 12.7% in South Asia (*) (Table 10.6) ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 16 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 16-52 Total pages: 173 Tourism in Europe reliant on snow at risk to higher levels of warming Soft: at 3°C, snowmaking as an adaptation measure limited by biophysical and financial constraints (***) (13.6.1.4, 13.6.2.3) Damages in European tourism with larger losses in Southern Europe (***) (13.6.1.4) Rapidly growing towns/cities and smaller cities at risk to range of climate hazards Soft: governance and financial constraints lead to limits in ability to adapt (6.3, 6.4) - 1 2 3 16.4.3.2 Constraints Leading to Limits to Adaptation 4 5 Across regions and sectors, a range of constraints (Figure 16.8) are identified as leading to limits to 6 adaptation, particularly financial constraints and constraints related to governance, institutions and policy 7 (high confidence). While individual constraints may appear straightforward to address, the combination of 8 constraints interacting with each other leads to soft limits that are difficult to overcome (high confidence). | Heritage | 2817 - 2818 |
| IPCC | IPCC_AR6_WGII_Full_Report | Social/cultural constraints (social status, caste and gender) also affect adaptation in contexts with deep-rooted traditions (Section 9.12.4). | Heritage | 2819 - 2819 |
| IPCC | IPCC_AR6_WGII_Full_Report | 25 Impacts on agriculture and food prices could force between 3 to 16 million people into extreme poverty 26 (Hallegatte and Rozenberg, 2017). Within-country inequality is expected to increase following extreme 27 weather events (Section 16.2.3.6 and Chapter 8). Households affected by climate-related extreme events may 28 be faced with continuous reconstruction efforts following extreme events (Adelekan and Fregene, 2015) or 29 declines in critical livelihood resources in the agriculture, fisheries and tourism sectors (Forster et al., 2014, 30 Section 3.5.1). Further erosion of livelihood security of vulnerable households creates the risk of poverty 31 traps, particularly for rural and urban landless (Section 8.2.1, Section 8.3.3.1), for example in Malawi and 32 Ethiopia (Section 9.9.3). Levels of labour productivity and economic outputs are projected to decrease as 33 temperatures rise particularly in urban areas (Section 6.2.3.1). At the same time, higher utilities demand 34 under higher urban temperatures exert additional economic stresses on urban residents and households. | Heritage | 2821 - 2821 |
| IPCC | IPCC_AR6_WGII_Full_Report | 22 23 KRs are determined not just by the nature of hazards, exposure, vulnerability, and response options, but also 24 by values, which determine the importance of a risk. Importance is understood here as the degree of 25 relevance to interpreting DAI at a given system's level or scale, and was an explicit criterion for identifying 26 key vulnerabilities and risks in AR5 (Oppenheimer et al., 2014). Because values can vary across individuals, 27 communities, or cultures, as well as over time, what constitutes a KR can vary widely from the perspective 28 of each of these groups, or across individuals. For example, ecosystems providing indirect services and 29 cultural assets such as historic buildings and archaeological sites may be considered very important to 30 preserve by some people but not by others; and some types of infrastructure, such as a commuter rail, may be 31 important to the well-being of some households but less so to others. Therefore, Chapter 16 authors do not 32 make their own judgements about the importance of particular risks. Instead, we highlight importance as an 33 overarching factor but identify and evaluate KRs based on four other criteria for what may be considered 34 potentially severe. | Heritage | 2822 - 2822 |

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| IPCC | IPCC_AR6_WGII_Full_Report | 44 45 Many KRs are especially prominent in particular regions or systems, or for particular subgroups of the 46 population. For example, coastal systems and small islands are a nexus of many KRs, including those to 47 ecosystems and their services, especially coral reefs; people (health, livelihoods); and assets, including 48 infrastructure. Risks to socio-ecological systems in polar regions are also identified as KRs, as are ecological 49 risks to the Amazon forest in South America and savannahs in Africa. For some regions risks from wildfire 50 are of particular concern, including in Australasia and North America. Vector-borne diseases are a particular 51 concern in Africa and Asia. Loss of cultural heritage is identified as a KR in Small Islands, Mountain 52 Regions, Africa, Australasia, and North America. | Heritage | 2823 - 2823 |
| IPCC | IPCC_AR6_WGII_Full_Report | Overlaps with key risk (v) 16.5.2.3.6 RKR-G Risk to water security Risk from water related hazards (floods and droughts) and water quality deterioration. Focus on water scarcity, water-related disasters and risk to indigenous and traditional cultures and ways of life Overlaps with key risk (iv) 16.5.2.3.7 RKR-H Risks to peace and to human mobility Risks to peace within and among societies from armed conflict as well as risks to low-agency human mobility within and across state borders, including the potential for involuntarily immobile populations. | Heritage | 2825 - 2825 |
| IPCC | IPCC_AR6_WGII_Full_Report | 5 6 16.5.2.3.1 Risk to the integrity of low-lying coastal socio-ecological systems (RKR-A) 7 RKR-A considers climate change-related risks to low-lying coasts including their physical, ecological and 8 human components. Low-lying systems are those occupying land below 10 m of elevation that is contiguous 9 and hydrologically connected to the sea (McGranahan et al., 2007). The assessment builds on Key Risks 10 identified in chapters 3 and 15, Cross Chapter Paper 2 as well as in the SROCC (Magnan et al., 2019; 11 Oppenheimer et al., 2019). It highlights risks to (i) natural coastal protection and habitats; (ii) lives, 12 livelihoods, culture and well-being; and (iii) critical physical infrastructure; it therefore overlaps with several 13 other RKRs (Fig. 16.10 and 16.11) but within a coastal focus. It encompasses all latitudes and considers 14 multiple sources of climate hazards, including sea-level rise (SLR), ocean warming and acidification, 15 permafrost thaw, and sea-ice loss and changes in weather extremes. | Heritage | 2826 - 2826 |
| IPCC | IPCC_AR6_WGII_Full_Report | 16 17 Severe risks to low-lying coasts involve irreversible long-term loss of land, critical ecosystem services, 18 livelihoods, well-being or culture in relation to increasing combined drivers, including climate hazards and 19 exposure and vulnerability conditions. The definition depends on the local context because of variation in the 20 perception of tolerable risks and the limits to adaptation (Handmer and Nalau, 2019). Accordingly, a 21 qualitative range of consequences is presented here, in place of a quantitative global severe risk threshold. | Heritage | 2826 - 2826 |
| IPCC | IPCC_AR6_WGII_Full_Report | 8 9 (ii) Impacts to lives, livelihoods, culture and well-being — In the absence of effective adaptation, changing 10 extreme and slow-onset hazards combined with anthropogenic drivers (e.g., increased population pressure at 11 the coast between +5% and +13.6% by 2100 compared to today, Jones and O'Neill, 2016) will lead to loss of 12 lives, livelihoods, health, well-being, and/or culture (McGregor et al., 2016; Pinnegar et al., 2019; Pugatch, 13 2019; Schneider and Asch, 2020; Thomas and Benjamin, 2020; McNamara et al., 2021) (high confidence). | Heritage | 2827 - 2827 |
| IPCC | IPCC_AR6_WGII_Full_Report | 14 Catastrophic examples that may foreshadow the future include Hurricane Sandy in 2012 (Strauss et al., 15 2021)and super Typhoon Haiyan in 2013 (>6,000 deaths and inequities in access to safe housing; Trenberth 16 et al. 2015) (6.2.2, 6.3.5.1). Although there is no unique definition of 'intolerable' loss, risks are generally 17 expected to become severe over this century (Tschakert et al., 2017; Dannenberg et al., 2019; Tschakert et 18 al., 2019). Globally, with High warming, 90 to 380 million more people will be exposed to annual flood 19 levels by the mid- and end-century, respectively, compared to 250 million people today (Kulp and Strauss, 20 2019; Kirezci et al., 2020), with potential implications on forced displacement or migration (Oppenheimer et 21 al., 2019; Wrathall et al., 2019; Hauer et al., 2020; Lincke and Hinkel, 2021, Section 16.5.2.3.9). Some of the 22 largest fish-producing and fish-dependent ecoregions have already experienced losses of up to 35% in 23 marine fisheries productivity due to warming (Free et al., 2019), and about 11% of the global population will 24 face increasing nutritional risks if current trajectories continue (Golden et al., 2016). While difficult to 25 measure, current climate-driven losses to (indigenous) knowledge, traditions (Tschakert et al., 2019; Pearson 26 et al., 2021) and well-being (Ebi et al., 2017; Cunsolo and Ellis, 2018; Jaakkola et al., 2018) indicate such 27 risk as already severe in some regions (low evidence, medium agreement), jeopardizing communities' 28 realization of their rights to food, health and culture. In the Arctic, climate-driven changes to ice and weather 29 regimes have substantially affected traditional coastal-based hunting and fishing activities (Fawcett et al., 30 2018; Galappaththi et al., 2019; Huntington et al., 2020; Nuttall, 2020, CCP6), and where permafrost thaw, 31 SLR and coastal erosion are contributing to threatening cultural sites (Hollesen et al., 2018; Fenger-Nielsen 32 et al., 2020). | Heritage | 2827 - 2827 |

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|---|---|---|---|---|
| IPCC | IPCC_AR6_WGII_Full_ Report | 8 Transport and energy infrastructure in coasts, polar systems and along rivers are projected to face a 9 particularly steep rise in risk, resulting in severe risk even under medium warming (high confidence). Risk in 10 relation to the increasing intensity and frequency of extreme events might become severe before the middle 11 of the century (medium confidence). Damages from multiple climate hazards to transport, energy, industry 12 and social infrastructure in Europe could increase tenfold by the 2080s, from 3.4 € billion annually to date, 13 and 15-fold for transport infrastructure, under Medium warming (A1B, ~3°C by 2100) and with current 14 adaptation levels, even if no further extension of the infrastructure in exposed areas is considered (Forzieri et 15 al., 2018). Under High warming (RCP8.5) in 2100, the percent of roads in the United States that require 16 rehabilitation due to high temperatures and precipitation is expected to increase to 23–33%, relative to 14% 17 in 2100 when no climate change is considered (Mallick et al., 2018). Projections of climate-induced changes 18 in exposure are an incomplete measure of risk but in the absence of other metrics can serve as a proxy for the 19 potential for severe impacts. In the circumpolar Arctic, 14.8% of critical infrastructure assets would be 20 affected by climate change under RCP8.5 by 2050, with lifecycle replacement costs projected to increase by 21 27.7% if infrastructure is to be preserved at current adaptation levels (Suter et al., 2019). Under RCP8.5, the 22 number of ports under high risk will increase from 3.8% in the present day to 14.4% by 2100, as a result of 23 increased coastal flooding and overtopping due to sea level rise, as well as the heat stress impacts of higher 24 temperatures (Izaguirre et al., 2021). In the UK under High warming (4ºC), the number of clean and 25 wastewater treatment sites located in the 1 in 75-year floodplain will increase by a third relative to today by 26 the 2080s under current vulnerability and adaptation levels (Dawson et al., 2018). A global assessment of 27 changing climate and water resources for electricity generation finds considerable reductions in usable 28 hydropower and thermoelectric capacity by 2050 for a range of warming scenarios from Low to High, with 29 absolute declines on average for most (61–74%) of the world's hydropower resources and monthly 30 maximum reductions above 30% of usable capacity for over two-thirds of 1,427 thermoelectric power plants 31 worldwide (Van Vliet et al., 2016). Many studies find large technical potential for coordinated adaptation- 32 mitigation policies in the electricity sector to avoid a significant portion of projected climate change impacts 33 (e.g., a two-thirds reduction, and in some cases fully offset) (Ciscar and Dowling, 2014; Van Vliet et al., 34 2016; Gerlak et al., 2018; Allen-Dumas et al., 2019). | Heritage | 2830 - 2830 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 3 4 16.5.2.3.7 Risk to water security (RKR-G) 5 Water security encompasses multiple dimensions: water for sanitation and hygiene, food production, 6 economic activities, ecosystems, water-induced disasters, and use of water for cultural purposes (Chapter 4; 7 Box 4.1; Section 4.6.1). Water security risks are a combination of water-related hazards such as floods, 8 droughts, and water quality deterioration, and exposure of vulnerable groups exposed to too little, too much, 9 or contaminated water. Reasons for these can include both environmental conditions and issues of safety and 10 access influenced by effectiveness of water governance (Sadoff et al., 2020). These are manifest through loss 11 of lives, property, livelihoods and culture, and impacts on human health and nutrition, ecosystems and water- 12 related conflicts which in turn can drive forced human displacement. | Heritage | 2836 - 2836 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 13 14 This RKR focuses on three types of risks with the potential to become severe: those associated with water 15 scarcity, those driven by water-related disasters, and those impacting indigenous and traditional cultures and 16 ways of life. Risk to water security constitutes a potentially severe risk because climate change could impact 17 the hydrologic cycle in ways that would lead to substantial consequences for the health, livelihoods, 18 property, and cultures of large numbers of people. For those associated with water scarcity, 'severe' refers to 19 magnitude (number of people in areas where water scarcity falls below recognised thresholds for adequate 20 water supply per capita), along with the likelihood of unforeseen increases in water scarcity that outpace the 21 ability to prepare for the increased risk by putting in place new large-scale infrastructure within the required 22 timescale. For those associated with extreme events, 'severe' refers to magnitude (numbers of people 23 affected, including deaths, physical health impacts including disease, mental health impacts, loss of 24 livelihoods, loss of or damage to property) and timing (for example, events coinciding with other stresses, 25 e.g., a pandemic occurring at a time when local infrastructures are weakened by an extreme weather event). | Heritage | 2836 - 2836 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 26 Important water-related extreme events include river flooding caused by heavy and/or prolonged rainfall, 27 glacial lake outburst floods, and droughts. For those impacting cultures, 'severe' refers to the loss of key 28 aspects of traditional ways of life. This includes consequences of the above two key risks. | Heritage | 2836 - 2836 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 31 32 Risks to cultural uses of water can become severe if there are permanent loss of aspects of communities' 33 cultures due to changes in water, including loss of areas of ice or snow with spiritual meanings, loss of 34 culturally-important places of access to such places, and loss of culturally-important subsistence practices 35 including by indigenous people (Chapter 4). This includes mountain regions where changes in the 36 cryosphere are having profound impacts (CCP5). In these cases, severe outcomes would be defined locally 37 rather than globally. Communities that lost a dominant environmental characteristic deeply associated with 38 its cultural identity would be considered to be severely impacted. For example, due to the central role that 39 travel on sea ice plays in the life of Inuit communities, providing freedom and mental wellbeing, loss of sea 40 ice can be argued to represent environmental dispossession of these communities (Durkalec et al., 2015). | Heritage | 2837 - 2837 |

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| IPCC | IPCC_AR6_WGII_Full_Report | 50 51 There is strong potential for increases in water scarcity, flooding, loss of snow and ice and changes in water 52 bodies to lead to severe outcomes such as deaths from water-related diseases, drowning and starvation, long- 53 term health impacts arising from malnutrition and diseases, loss of property, loss of existence or access to 54 places of cultural significance, loss of livelihoods and loss of aspects of culture especially for indigenous 55 people with traditional lifestyles. The numbers of people affected are projected to range from hundreds of 56 millions to several billion, depending on the level of global warming and socio-economic futures. A key 57 aspect of the risk is the high uncertainty in future regional precipitation changes in many regions of high ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 16 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 16-72 Total pages: 173 1 vulnerability, including the potential for large and highly-impactful changes, for which it may not be 2 possible to provide adaptation measures before they become needed, leading to a high likelihood of 3 adaptation deficits. | Heritage | 2837 - 2838 |
| IPCC | IPCC_AR6_WGII_Full_Report | 53 In AR6, moderate risks have already been assessed to have occurred in Africa for economic growth and 54 reduced inequality, biodiversity and ecosystems, mortality and morbidity due to heat extremes and infectious 55 disease, and food production in fisheries and crop production (Figure 9.6). In Europe moderate risks to heat 56 stress, mortality and morbidity have already been reached, as well as for water scarcity in some regions 57 (Figure 13.30, Figure 13.33). In Australasia, moderate risks are assessed as present already for heat related ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 16 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 16-107 Total pages: 173 1 mortality risk as well as cascading effects on cities and settlements; and also very high risks already present 2 in coral reef systems, and high risks to kelp forests and alpine biodiversity (Figure 11.7). In North America, 3 moderate risks have already been reached for freshwater scarcity, water quality (Figure 14.4), agriculture, 4 forestry, tourism, transport, energy & mining and construction (Figure 14.10). | Heritage | 2872 - 2873 |
| IPCC | IPCC_AR6_WGII_Full_Report | 39 40 High risks to crop production are assessed to occur in Africa ~1.5-2ºC warming (Figure 9.6), to agriculture 41 in North America for ~1.5ºC warming (Figure 14.10), and ~ 2.8ºC Europe (Figure 13.30). High risks of 42 mortality and morbidity due to heat extremes and infectious disease are assessed to be reached in Africa with 43 ~1.5ºC warming (Figure 9.6); heat stress, mortality and morbidity in Europe is assessed to reach a high level 44 of risk at ~2ºC (Figure 13.30). Heat related mortality risk transitions to a high level by ~1.5-2ºC warming in 45 Australasia while cascading effects on cities reach high risk with ~1.2ºC warming (Figure 11.7). Risks to 46 water scarcity, forestry, tourism and transportation in N America are projected to reach high levels with ~2ºC 47 warming (Figure 14.4, Figure 14.10). | Heritage | 2873 - 2873 |
| IPCC | IPCC_AR6_WGII_Full_Report | 9 10 [END BOX 17.2 HERE] 11 12 13 17.2.2.3 Adaptation Beyond Risk: Exploiting Opportunities 14 15 Several studies and many government planning documents reference how people can benefit from a changed 16 climate, beyond reducing risks. For example, several regions are expecting an increase in visitors to eco- 17 tourism sites or national parks with a changing climate (Fisichelli NA, 2015; Lwasa, 2015). In Europe, 18 several national adaptation plans include planning for potential benefits of a changing climate, including 19 reduced winter mortality and improved conditions for hydropower (Biesbroek et al., 2010). Recognizing the 20 need for economic diversification, people working in certain industries, such as coastal management, 21 perceive climate change as a factor increasing the need for their services (Fatorić et al., 2017). Northern 22 countries are taking advantage of ice-free waters for shipping routes in the Arctic (Eguiluz et al., 2016; Melia 23 et al., 2016; IPCC, 2019e-a). In Africa, opportunistic adaptation has been observed by smallholder farmers, 24 who plant crops that are better suited for a changing climate (Lalou et al., 2019). Similar agricultural 25 adaptation in Pakistan has been associated with improved food security and reduced poverty (Ali and 26 Erenstein, 2017; Rahman et al., 2020). In each of these cases documenting benefits, there are also potential 27 negative impacts on other populations or ecosystems, such as ecosystem impacts from increased Arctic 28 shipping (Ng et al., 2018). | Heritage | 2963 - 2963 |
| IPCC | IPCC_AR6_WGII_Full_Report | 30 Some behavioural adaptations, such as changing diets and reducing food waste, can also require large 31 transformations in land use and food culture (medium confidence). Spatial planning, including urban zoning, 32 also tends to be more transformative (medium confidence). | Heritage | 2964 - 2964 |
| IPCC | IPCC_AR6_WGII_Full_Report | Health care systems** Facilities in poor communities are often poorly sited and can lack capacity to support Universal health coverage can be highly beneficial to poor people (Atun et al., 2015), ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 17 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 17-28 Total pages: 156 people during climate-related extreme events (Codjoe et al., 2020). | Heritage | 2966 - 2967 |
| IPCC | IPCC_AR6_WGII_Full_Report | 1 2 3 17.2.2.5 Incremental and Transformational Adaptation for Managing Risk in the Context of Adaptation 4 Limits 5 6 With evidence on soft and hard limits being experienced in natural and human systems including in 7 terrestrial, aquatic and marine ecosystems, coastal and island systems, agriculture, health systems, urban 8 spaces and tourism (Table 16.5, 16.4.2, medium confidence) transformation is also being considered to 9 expand the adaptation space beyond soft limits and before hard limits are being reached. As a key area of 10 advancement since AR5, this section assesses the relationship of residual risks, limits and incremental as 11 well transformational adaptation integrating the assessment of limits in 16.4 with ch.17 adaptation and risk 12 management assessment along a spectrum of adaptation change. 17.2.2.5 thus contributes to understanding 13 in which systems and regions transformational adaptation is increasingly required and considered once 14 incremental adjustments are exhausted in the context of soft and hard limits. | Heritage | 2967 - 2967 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 21 22 Planned adaptation can help to buy some limited time including through recovery and restoration efforts that 23 target resistant coral populations and interventions to culture heat-tolerant algal symbionts as well as by 24 setting up marine protected areas. Under higher warming levels, transformation has been proposed as 25 possibly complementing available management approaches with high-risk interventions, including enhanced 26 corals and reef shading, which may help to sustain some coral reef systems beyond 1.5°C of global warming. | Heritage | 2969 - 2969 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 34 35 In terms of planned adaptation options that would provide benefits to populations, evidence suggest these are 36 very limited, uncertain and bring along substantial risks to people, culture and ecosystems (3.5.2. Cross- 37 Chapter Box SLR). Concurrent with the loss of coral reefs important ecosystem services, including to RKR-E: Risk to human health from heat • Observed impacts • Projected risks • Incremental adaptation complemented by • Transformational adaptation • Soft limit (to incremental adaptation) • Hard limit Confidence: * low ** medium *** high **** very high ***** virtually certain Global • Heat is a significant health risk due to widespread urbanization, demographic changes and increase in hot weather (***) 323,000 estimated heat-related deaths and 13 million heat-related DALYs in 2019 • Temperature-related mortality expected to increase under medium and high heating scenarios even with adaptation. By 2050 (compared to 1961-1991) an excess of 94,000 deaths per year attributable to climate change projected due to heat for medium warming. | Heritage | 2969 - 2969 |
| IPCC | IPCC_AR6_WGII_Full_ Report | • Limited evidence reported. early warning and response systems; integrating climate services into health decision-making systems; public uptake and buy in; improving health data collection systems • No evidence if transformational adaptation. • Reduced habitability of small islands through a compounding of key risks including from heat-related health stress for warming of 1.5 ° degrees (***) ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 17 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 17-31 Total pages: 156 1 fishery, tourism and coastal protection would be lost. Transformational adaptation, while requiring to make 2 difficult choices, is being discussed to help overcome soft limits through livelihood diversification for 3 alternative income sources, assisted migration and planned relocation of communities dependent on the 4 services provided by the reef ecosystem (medium confidence) (3.5.2). | Heritage | 2969 - 2970 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 17 18 There is evidence that, without strong risk management and adaptation, losses and damages will continue to 19 affect the poorest vulnerable populations potentially creating poverty traps (high confidence) (8.3; 8.4.5.6 20 and Table 8.7; 17.2; Serdeczny, 2019; Tschakert et al., 2019; Thomas et al., 2020). Research has started to 21 develop global inventories on losses and damages including on intangible effects (Tschakert et al., 2019; 22 Otto et al., 2020) and engaged with the practice community for data collection. Practice has provided 23 guidance to report on losses and damages in countries' (I)NDCs (WWF & Practical Action, 2020). Yet, 24 systematic risk assessments of climate-related losses and damages including adaptation limits (see, e.g. Leal 25 Filho and Nalau, 2018; Robinson, 2018) have remained scarce (16.4; high confidence). Thus many 26 vulnerable countries lack comprehensive data at scale of risk management including on economic (e.g. loss 27 of livelihood assets and infrastructure), and non-economic losses and damages (e.g. culture, health, 28 biodiversity) thus hampering effective risk management (Thomas and Benjamin, 2018; Martyr-Koller et al., 29 2021; Singh et al. 2021). van den Homberg and McQuistan (2019) propose a losses and damages inventory 30 also to be used to monitor how technologies may shape risks as well as adaptation limits. While early 31 warning and other risk reduction options as well as risk retention considerations are being discussed, L&D 32 dialogue has strongly focussed on risk finance for residual risks, particularly through the donor-supported 33 provision of public insurance systems (Linnerooth-Bayer et al., 2019; Schäfer et al., 2019; Broberg and 34 Romera, 2020; Nordlander et al., 2020). | Heritage | 2971 - 2971 |
| IPCC | IPCC_AR6_WGII_Full_ Report | Multi-Criteria Decision Analysis (MCDA): Partial ranking (Roy, 1996; Bell et al., 2001; Belton and Stewart, 2002; Bouyssou et al., 2006; Behzadian et al., 2010; Zopounidis and Pardalos, 2010; Tzeng and Huang, 2011; Bouyssou and others, 2012; De Smet and Lidouh, 2012; Velasquez and Hester, 2013; Figueira et al., 2016; Govindan and Jepsen, 2016) Examples include developing criteria for assessing climate protection strategies and applying these to retrofitting a school to manage climate risks in Germany (Markl-Hummel and Geldermann, 2014); evaluating outranking approaches for managing heat stress in a large city in Australia (El-Zein and Tonmoy, 2015); using MCDA to manage the interactions of climate change with tourism in Greece (Michailidou et al., 2016); and identifying priorities to manage droughts and floods in agriculture in Bangladesh (Xenarios and Polatidis, 2015). | Heritage | 2985 - 2985 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 39 40 17.3.1.3.2 Stakeholder engagement 41 Stakeholder engagement has become increasingly part of climate-relevant decision processes (Orlove et al., 42 2020). The degree of stakeholder engagement ranges from instructive, consultative to cooperative that are 43 equivalent to information exchange, influence, and partners in decision-making (Sen, 2000; Cattino and 44 Reckien, in press). Since the AR5, climate change adaptation and resilience literature has seen an increase in 45 participatory approaches that deepen engagement and overcome challenges, as well as making some 46 assessments of their effectiveness (Newton Mann et al., 2017; Wamsler, 2017; Esteve et al., 2018), including 47 structured interactions among different types of stakeholders, the use of place-based boundary organizations 48 to strengthen the interactions and heighten the awareness of the institutional context. A higher degree of 49 public participation can lead to more transformational adaptation as well as to higher ambition for local 50 mitigation (medium confidence) (17.4.4.2; Cattino and Reckien, in press). Challenges to stakeholder 51 participation are access to state-of-the-art science, capacity to recognize and respond to non-reliable or false 52 climate science information, and the removal of cognitive and other biases (high confidence) (Gorddard et 53 al., 2016; Engler et al., 2019; Fulton, 2021). | Heritage | 2988 - 2988 |

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| Organisation | Document | Quotation Content | Codes | Page |
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| IPCC | IPCC_AR6_WGII_Full_ Report | 26 This can identify the range of existing legislative instruments that can directly intersect with climate change, 27 along with related contextual factors such as national circumstances, governance frameworks, and political 28 and economic realities as well as national administrative culture (Scotford et al., 2017). This helps any new 29 climate change laws to be absorbed into, and harmonise with, the established legal system of each country 30 (Scotford et al., 2017). Efforts are underway to assist countries in such assessments and the identification of 31 areas for legislative reform, for example through the Commonwealth and UN Environment's Law and 32 Climate Change Toolkit. Similarly, databases such as the Grantham Research Institute on Climate Change 33 and the Environment and the Sabin Center on Climate Change Law are expanding the knowledge base of 34 national climate legislation developments. | Heritage | 2996 - 2996 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 6 7 Several other international agreements including the Sendai Framework for Disaster Risk Reduction and the 8 UN Agenda 2030 Sustainable Development Goals have had significant impacts on the adaptation and risk- 9 management decision-making processes. For example, the Sendai Framework articulates the need for 10 improved understanding of disaster risk in all its dimensions of exposure, vulnerability and hazard 11 characteristics; accountability for disaster risk management; preparedness to "Build Back Better"; 12 recognition of stakeholders and their roles; mobilization of risk-sensitive investment to avoid the creation of 13 new risk resilience of health infrastructure, cultural heritage and workplaces; strengthening of international 14 cooperation and partnership, and risk-informed donor policies and programs, including financial support and 15 loans from international financial institutions. | Heritage | 2998 - 2998 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 8 9 Practitioner knowledge—the pragmatic, practice-based knowledge that comes from the regular exercise of 10 craft or professional work—was also acknowledged briefly in AR5 (Jones et al., 2014) and treated 11 significantly in SROCC (Abram et al., 2019). Practitioner knowledge resembles local knowledge in that it is 12 acquired through participation in activities, and yet it differs from local knowledge, which is often place- 13 based and tied directly to specific landscapes and communities. Local knowledge typically covers a variety 14 of environmental domains. Practitioner knowledge may be shared with people in different locations and is 15 often more focused on a narrower set of work activities. Recent calls have recommended bringing 16 practitioners more fully into the IPCC assessment process, to promote more effective decision-making 17 (Howarth et al., 2018). | Heritage | 3011 - 3011 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 25 26 The perception of climate change as a major threat that requires action has increased since AR5, reflecting 27 both the growth of information about climate change and the processing of that information (Lee et al., 2015; 28 Fagan and Huang, 2019). Global social movements play an important role in raising public awareness of 29 climate urgency (Thackeray et al., 2020). Climate change concern plays an important role in decision- 30 making outcomes which entail public participation (Lammel, 2015; Chiang, 2018; van Valkengoed and Steg, 31 2019; Arıkan and Günay, 2020). Nonetheless, public risk perception varies sharply on spatial and temporal 32 scales, reflecting environmental changes, social influences (Kousser and Tranter, 2018; Rousseau and 33 Deschacht, 2020), economic capacities (Arıkan and Günay, 2020) and culture (Noll et al., 2020), as well as 34 individual characteristics (van Valkengoed and Steg, 2019). The importance of values and norms is 35 demonstrated by recent research which highlights how intrinsic motivation (altruistic, self-transcendental and 36 ecocentric values) (Corner et al., 2014; Braito et al., 2017; Xiang et al., 2019; Bouman et al., 2020) and 37 extrinsic social motivation (e.g., economic gains and social desirability) (van Valkengoed and Steg, 2019) 38 can drive action. | Heritage | 3014 - 3014 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 13 14 Extreme events such as disasters often act as proximate drivers of windows of opportunity (Birkmann and 15 Fernando, 2008; McSweeney and Coomes, 2011). Climate disasters in a specific location become significant 16 windows for new debate, policymaking and financing (McSweeney and Coomes, 2011). Extreme events also 17 can facilitate change at locations distant from the most impacted site when remote actors gain perspective on 18 their own risks (Friedman et al., 2019; Solecki et al., 2019). Factors that facilitate extreme events driving 19 proactive as opposed to reactive responses include access to relevant risk and vulnerability data, pre-existing 20 experience with similar events, and appropriate governance (Brown et al., 2017a). Page and Dilling (2020) 21 find that worldview or ideology plays a central role in sense-making and in shaping what organizational 22 decision-makers 'see' in terms of acceptable actions in response to an extreme event. | Heritage | 3017 - 3017 |
| IPCC | IPCC_AR6_WGII_Full_ Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 17 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 17-81 Total pages: 156 1 2 These movements usually focus on climate mitigation but sometimes include adaptation. Their social bases 3 include groups which had not previously been active in climate politics, notably children and youth, as well 4 as sectors with long traditions of environmental activism, such as women and Indigenous peoples (see Cross- 5 Chapter Boxes GENDER and INDIG in Chapter 18). Much of the literature on youth movements traces the 6 emergence of the movements themselves (Sanson et al., 2019; Treichel, 2020), their framings of climate 7 change as a social justice issue (Holmberg and Alvinius, 2019) and their presence in demonstrations and on 8 social media (Boulianne et al., 2020). Climate action catalysed by youth and other climate movements 9 include visible international events such as the signing of Declaration on Children, Youth, and Climate 10 Action at COP25 in Madrid 2019 (Han and Ahn, 2020), as well as national efforts, including lawsuits, and 11 local events such as in tree-planting and waste reduction initiatives (Bandura and Cherry, 2019). | Heritage | 3019 - 3020 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 6 7 8 [START BOX 17.3 HERE] 9 10 Box 17.3: Climate Risk Decision-Making in Settlements: From Incrementalism to Transformational 11 Adaptation 12 13 Cities are important sites of experimentation where the integration and management of adaptation decision- 14 making complexity often takes place. These actions provide early evidence of what aspects of complex 15 climate risk management decision-making functions well, but also what does not work (Revi et al., 2020). | Heritage | 3021 - 3021 |

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| IPCC | IPCC_AR6_WGII_Full_Report | 22 Three key sets of drivers influence risk management decision-making in cities (Solecki et al., 2017). These 23 include 1) root – i.e., cultural norms and social traditions; 2) context – i.e., policy and governance conditions 24 and 3) proximate – i.e., extreme events. Settlements have developed informal and formal strategies including 25 climate protection levels to respond to local conditions of climate risk and hazards. In formal contexts, these 26 strategies are contextualized in local climate change action plans (Araos et al., 2016a; Stults and Woodruff, 27 2017; Reckien et al., 2018a; Singh et al., 2021) and defined around a set of evaluation tools and methods and 28 building codes, standards, and regulations (see discussion in 17.4.4). | Heritage | 3021 - 3021 |
| IPCC | IPCC_AR6_WGII_Full_Report | 26 27 Under the Paris Agreement countries are encouraged to provide information on adaptation including its 28 adequacy and effectiveness (Möhner et al., 2017; Adaptation Committee, 2021). National adaptation M&E 29 systems can inform both national as well as international reporting and contribute to the global stocktake (see 30 Cross-Chapter Box PROGRESS in this Chapter; Craft and Fisher, 2015; Leiter et al., 2017a). Guidance for 31 and examples of national adaptation progress assessments are provided by Price-Kelly et al. (2015); Brooks 32 et al. (2014); Brooks et al. (2019); EEA (2015); GIZ (2017); Karani (2018); and van Rüth and Schönthaler 33 (2018). Global assessments of adaptation progress have so far often focused on adaptation planning and, to a 34 lesser extent, implementation whilst evidence of the collective effect of adaptation globally remains limited 35 (high confidence) (UNEP, 2021a; Cross-Chapter Box PROGRESS in this Chapter). | Heritage | 3033 - 3033 |
| IPCC | IPCC_AR6_WGII_Full_Report | 37 38 Assessing global progress on adaptation is therefore of high relevance to the scientific community, to policy 39 makers and other actors. Global assessments serve different information needs than local assessments and 40 their meaningfulness depends on the chosen approaches and their limitations. Aggregated global assessments 41 of adaptation progress are therefore not meant to substitute place-specific ones but to complement them to 42 enhance the knowledge base on adaptation beyond actions by or within individual countries. The Paris 43 Agreement stipulates a Global Stocktake to be undertaken every five years to assess the collective progress 44 towards its long-term goals including on adaptation (UNFCCC, 2015, Article 14). Yet very few scientific 45 studies have addressed the adaptation-specific aspects of the Global Stocktake (Craft and Fisher, 2018; 46 Tompkins et al., 2018) and there are different views and options on how assessing global progress could take 47 place (high confidence). | Heritage | 3035 - 3035 |
| IPCC | IPCC_AR6_WGII_Full_Report | 9 10 Learning requires information about how and why change occurred and what experiences have been made 11 (Feinstein, 2012). M&E is frequently associated with learning, but it is rarely made explicit how learning is 12 supposed to take place (Armitage et al., 2008; Baird et al., 2015; Borras and Hølund, 2015). The design of 13 adaptation M&E systems can support learning by gathering relevant information and disseminating it in a 14 way that is accessible and effectively linked to decision making processes (Spearman and McGray, 2011; 15 Villanueva, 2012; Fisher et al., 2015). Options include institutionalised feedback mechanisms, peer learning 16 and knowledge sharing events, a learning culture and ways to gather in-depth insights beyond indicators 17 (ibid; Oswald and Taylor, 2010). Since AR5, adaptation programmes and funds such as the BRACED 18 programme, the Adaptation Fund, the Climate Investment Funds and the Green Climate Fund have created 19 knowledge-sharing units and provide resources to support learning activities(BRACED, 2015; Roehrer and 20 Kouadio, 2015; Adaptation Fund, 2016; Leavy et al., 2018; CIF, 2020; Puri et al., 2020), but there is little 21 information about their longer-term effectiveness. | Heritage | 3040 - 3040 |
| IPCC | IPCC_AR6_WGII_Full_Report | 15 16 In a warming world, incremental adaptation, i.e. proven standard measures of adaptation, will not always 17 suffice to adjust to the negative impacts from climate change leading to substantial residual risks and, in 18 some cases, the breaching of adaptation limits; transformational adaptation, involving larger system-wide 19 change (as compared to in system change), will increasingly be necessary as a complement for helping 20 individuals and communities to cope with climate change. As an example of incremental adaptation, a 21 farmer may decide to use drought-tolerant crops to deal with increasing occurrences of heatwaves. With 22 further warming and increases in heat waves and drought, however, the impacts of climate change may 23 necessitate the consideration of system-wide change, such as moving to an entirely new agricultural system 24 in areas where the climate is no longer suitable for current practices; or switching to livestock rearing. Where 25 on-site adaptation becomes infeasible and pull factors exist, the farming households may decide to seek 26 employment in other sectors, which may also lead to migration for work. As another example, physical 27 protection through sea walls to stop coastal flooding is a proven adaptation measure. With further projected 28 flooding due to increasing sea level rise attributable to climate change transformational city planning, that 29 would systemically change how flood water is managed throughout the whole city requiring deeper 30 institutional, structural, and financial support, may become necessary. Also, the deliberate relocation of 31 settlements (managed retreat) is seeing attention in the face of increasingly severe coastal or riverine 32 flooding in some regions. While transformational adaptation is increasingly being considered in theory and 33 planning, implementation is only beginning to see attention. | Heritage | 3045 - 3045 |

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| Organisation | Document | Quotation Content | Codes | Page |
|---|---|---|---|---|
| IPCC | IPCC_AR6_WGII_Full_ Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 18 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 18-12 Total pages: 197 1 2 3 4 Figure 18.2: Societal choices in arenas of engagement shaping actions and systems. The settings, places and spaces 5 in which key actors from government, civil society and the private sector interact to influence the nature and course of 6 development can be called arenas of engagement, including political, economic, socio-cultural, ecological, knowledge- 7 technology and community arenas. For instance, political arenas include formal political settings such as voting 8 procedures to elect local representatives as well as less formal and transparent political arenas. Streets, town squares 9 and post-disaster landscapes can become sites of interaction and political struggle as citizens strive to have their voices 10 heard. Arenas exist across scales from the local to national level, and beyond. Arenas of engagement can take the form 11 of “struggle arenas” – in which power and influence are used to include/exclude, set agendas, and make and implement 12 decisions – with inevitable winners and losers. The quality of interactions in these arenas leads to development 13 outcomes that can be characterized as CRD dimensions that underpin the SDGs – people, prosperity, partnership, peace, 14 planet (see Figure 18.1). a) Interactions characterized by inequitable relations and domination of some actors over 15 others may lead to societal choices away from CRD, including exacerbating disempowerment and vulnerability among 16 marginalized groups. b) Prospects for moving towards CRD increase when governance actors work together 17 constructively in these different arenas. Interactions and actions that are inclusive and synchronous, as opposed to 18 fragmented or contradictory, enable system transitions and transformational change towards CRD (Figure 18.3b, Box 19 18.3). b) Well-intentioned efforts often fail to be transformative, but instead entrench inequities. Instead, marginalized 20 groups and future trends in vulnerability need to be placed at the center of efforts to chart CRDPs. Unlocking the 21 productive potential of conflict that often characterizes interactions in these arenas of engagement is central to 22 advancing human well-being and planetary health. Moreover, the window for doing so is closing rapidly to avert 23 dangerous climate change and unsustainable development. | Heritage | 3106 - 3107 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 20 21 [END BOX 18.1 HERE] 22 23 24 [START BOX 18.2 HERE] 25 26 Box 18.2: Visions of Climate Resilient Development in Kenya 27 28 The Government of Kenya’s (GoK) ambition is to transform Kenya into a ‘newly industrializing, middle- 29 income country providing a high-quality life to all its citizens by 2030 in a clean and secure environment’ 30 (Government of Kenya, 2008). Dryland regions in Kenya occupy 80-90 per cent of the land mass, are home 31 to 36% of the population (Government of Kenya, 2012) and contribute about 10 per cent of Kenya’s Gross 32 Domestic Product (GDP) (Government of Kenya, 2012) which includes half of its agricultural GDP 33 (Kabubo-Mariara, 2009). In dryland regions, pastoralism has long been the predominant form of livelihood 34 and subsistence (Catley et al., 2013; Nyariki and Amwata, 2019). The GoK seeks to improve connectivity 35 and communication infrastructure within the drylands to better exploit and develop livestock, agriculture, 36 tourism, energy, and extractive sectors (Government of Kenya, 2018). It argues that the transformation of 37 dryland regions is crucial to enhance the development outcomes for the more than 15 million people who 38 inhabit these areas (Government of Kenya, 2016: 17) and to help the country to realize its wider national 39 ambitions including a 10 percent year on year growth in GDP (Government of Kenya, 2012). A key element 40 within this vision is the promotion and implementation of the Lamu Port South Sudan Ethiopia (LAPSSET) 41 project, a 2,000km long, 100 km wide economic and development corridor extending from Mombasa to 42 Sudan and Ethiopia (Enns, 2018). Supporters of the LAPSSET project argue that it will help achieve 43 priorities laid out in the Vision 2030 by opening up poorly connected regions, enabling the development of 44 pertinent economic sectors such as agriculture, livestock and energy, and supporting the attainment of a 45 range of social goals made possible as the economy grows (Stein and Kalina, 2019). | Heritage | 3112 - 3112 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 46 47 However, the development narrative surrounding LAPSSET remains controversial in its assumptions, not 48 least because it is being promoted in the context of a highly complex and dynamic social, economic and 49 biophysical setting (Cervigni and Morris, 2016; Atsiaya et al., 2019; Chome, 2020; Lesutis, 2020). Some of 50 the key trends driving contemporary and likely future change in dryland regions are changing household 51 organization, evolving customary rules and institutions at local and community levels, and shifting cultures 52 and aspirations (Catley et al., 2013; Washington-Ottombre and Pijanowski, 2013; Tari and Pattison, 2014; 53 Cormack, 2016; Rao, 2019). Dryland regions are also witnessing demographic growth and change in land- 54 use patterns linked to shifts in the composition of livestock (for example from grazers to browsers), a 55 decrease in nomadic and increase in semi-nomadic pastoralism, and transition to more urban and sedentary 56 livelihoods (Mganga et al., 2015; Cervigni et al., 2016; Greiner, 2016; Watson et al., 2016). At a landscape 57 level, land is becoming more fragmented and enclosed, often associated with increases in subsistence and ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 18 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 18-18 Total pages: 197 1 commercial agriculture, and the establishment of conservancies and other group or private land holdings 2 (Reid et al., 2014; Carabine et al., 2015; Nyberg et al., 2015; Greiner, 2016; Mosley and Watson, 2016). In 3 addition, there are political dynamics associated with Kenya Vision 2030 and decentralization, the influence 4 of international capital, foreign investors and incorporation into global markets (Cormack, 2016; Kochore, 5 2016; Mosley and Watson, 2016; Enns and Bersaglio, 2020), as well as increasing militarization and conflict 6 in the drylands (Lind, 2018). Allied to these social and political dynamics are ongoing processes of habitat 7 modification and degradation and biophysical changes linked in part to climate variability (Galvin, 2009; 8 Mganga et al., 2015). The interconnected nature of these drivers will intersect with LAPSSET in myriad 9 ways. For example, the implementation of LAPSSET may accentuate some trends, such as increases in land 10 enclosure and a shift towards more urban and sedentary livelihoods (Lesutis, 2020). Conversely, the 11 perceived threat LAPSSET could pose to pastoral lifestyles may lead to greater visibility, solidarity and 12 strength of pastoralist institutions (Cormack, 2016). | Heritage | 3112 - 3113 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 13 14 There is a recognized need to adapt and chose development pathways that are resilient to climate change 15 whilst addressing key developmental challenges within dryland regions, notably, poverty, water and food 16 insecurity, and a highly dispersed population with poor access to services (Government of Kenya, 2012; 17 Bizikova et al., 2015; Herrero et al., 2016). The current vision for development of dryland regions comes 18 with both opportunities and threats to achieve a more climate resilient future. For example, the growth in and 19 exploitation of renewable energy resources, made possible through increased connectivity, brings climate 20 mitigation gains but also risks. These risks include the uneven distribution of costs in terms of where the 21 industry is sited compared with where benefits primarily accrue, and may exacerbate issues around water 22 and food insecurity as strategic areas of land become harder to access (Opiyo et al., 2016; Cormack and 23 Kurewa, 2018; Enns, 2018; Lind, 2018). Whilst LAPSSET will bring greater freedom of movement for 24 commodities, benefitting investors, improving access to markets and urban centers, supporting trade, or ease 25 of movement for tourists supporting economic goals, it can also result in the relocation of people and impede 26 access to certain locations for the resident populations. Mobility is a key adaptation behavior employed in 27 the short and long term to address issues linked with climatic variability (Opiyo et al., 2014; Muricho et al., 28 2019). With modelled changes in the climate suggesting decreases in income associated with agricultural 29 staples and livestock-dependent livelihoods, development that constrains mobility of local populations could 30 retard resilience gains (Ochieng et al., 2017; ASSAR, 2018; Enns, 2018; Nkemelang et al., 2018). The likely 31 increase in urban populations and the growth in tourism and agriculture may lead to increases in water 32 demand at a time when water availability could become more constrained owing to the reliance on surface 33 water sources and the modelled increases in evapotranspiration due to rising mean temperature, more 34 heatwave days and greater percentage of precipitation falling as storms (ASSAR, 2018; Nkemelang et al., 35 2018; USAID, 2018). These pressures could make it harder to meet basic health and sanitation goals for rural 36 and poorer urban populations, issues compounded further by likely increases in child malnutrition and 37 diarrheal deaths linked to climate change (WHO, 2016; ASSAR, 2018; Hirpa et al., 2018; Nkemelang et al., 38 2018; Lesutis, 2020). Development must pay adequate attention to these interconnections to ensure that costs 39 and benefits of achieving climate mitigation and adaptation goals are distributed fairly within a population. | Heritage | 3113 - 3113 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 49 50 One common approach for exploring the implications of different development trajectories is the use of 51 scenarios of future socioeconomic conditions, such as the Shared Socioeconomic Pathways (SSPs) (O'Neill 52 et al., 2017). The SSPs represent sets of future global societal assumptions based on different societal, 53 technological, and economic assumptions that result in different development trajectories. Such scenarios 54 often correspond to a small set of scenario archetypes (Harrison et al., 2019; Sitas et al., 2019; Fergnani and 55 Song, 2020) in that they reflect core themes regarding the future of development such as sustainability versus 56 rapid growth. Scenarios with assumptions more closely aligned with sustainability agendas (e.g., SSP1- 57 Sustainability) commonly imply lower greenhouse gas emissions and projected climate change (see WGIII ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 18 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 18-23 Total pages: 197 1 AR6 Chapter 3), lower mitigation costs for ambitious climate goals (see WGIII AR6 Chapter 3), lower 2 climate exposure due in large part to the size of society (see Chapter 16), and greater adaptive capacity (Roy 3 et al., 2018) (see also Chapter 16). In contrast, scenarios with rapid global economic and fossil energy 4 growth (e.g., SSP5-Fossil-Fueled Development) imply higher emissions and project climate change, higher 5 mitigation costs, as well as greater social and economic capacity to adapt to climate change impacts (Hunt et 6 al., 2012) (Table 18.1). | Heritage | 3117 - 3118 |
| IPCC | IPCC_AR6_WGII_Full_ Report | Developmen t Indicator Releva nt SDG Shared Socioeconomic Pathway Confiden ce Evidence/ Agreeme nt References Sustainabili ty (SSP1) Middl e of the Road (SSP2 ) Region al Rialry (SSP3) Inequalit y (SSP4) Fossil�fueled Developme nt (SSP5) Agriculture, Food, & Forestry •Agriculture production •Forestry production •Food security •Hunger SDG 2 & 1 ( ( ( Low Agreemen t/ Robust Evidence (Hasegawa et al., 2015; Palazzo et al., 2017; Riahi et al., 2017; Duku et al., 2018; Chen et al., 2019; Daigneault et al., 2019; Mitter et al., 2020; Mora et al., 2020) Health & Well-Being • Exces s mortality • Air quality SDG 3 1 1 1 ( ( Medium Agreemen t/ Robust Evidence (Chen et al., 2017; Mora et al., 2017; Aleluia Reis et al., 2018; Asefi�Najafabady ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 18 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 18-24 Total pages: 197 • Vecto r-borne disease • Life Satisfaction et al., 2018; Chen et al., 2018; Harrington and Otto, 2018; Marsha et al., 2018; Sellers and Ebi, 2018; Ikeda and Managi, 2019; Rohat et al., 2019; Wang et al., 2019; Chae et al., 2020) Water & Sanitation • Water use • Sanitation access • Sewage discharge SDG 6 & ( ( 1 1 High Agreemen t/ Medium Evidence (Wada et al., 2016) (van Puijenbroek et al., 2014; Yao et al., 2017) (Mouratiad ou et al., 2016; Graham et al., 2018) Inequality • Gini coefficient SDG 10 & & & 1 & Medium Agreemen t/ Limited Evidence (Rao et al., 2019b; Emmerling and Tavoni, 2021; Gazzotti et al., 2021) Ecosystems and Ecosystem Services •Aquatic resources •Urban expansion •Habitat provision •Carbon sequestrati on •Biodiversit y SDG 14 SDG 15 ( ( ( ( ( High Agreemen t/ Medium Evidence (Li et al., 2017; Chen et al., 2019; Li et al., 2019b; Chen et al., 2020b; Song et al., 2020b; McManama y et al., 2021; Pinnegar et al., 2021) Legend $ Balance of studies suggest large increasing threat to sustainable development ( Balance of studies suggest moderate increasing threat to sustainable development 1 Studies suggest both threats and benefits to sustainable development & Balance of studies suggest moderate increasing benefit to sustainable development # Balance of studies suggest large increasing benefit to sustainable development Table Notes: Studies presented in the above table include qualitative storylines and quantitative scenarios for two or more SSPs. | Heritage | 3118 - 3119 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 26 27 28 [START BOX 18.3 HERE] 29 30 Box 18.3: Climate Resilient Development in Small Islands 31 32 Small Islands are particularly vulnerable to climate change and many are already pursuing climate resilient 33 development pathways that enable integrated responses (Allen et al., 2018a; Mycoo, 2018; Hay et al., 2019; 34 Robinson et al., 2021). Countries, such as Belize, have opted for a systems-approach and are working across 35 the SDGs to increase integration (Allen et al., 2018a). This includes rethinking disaster reconstruction 36 mechanisms in the Caribbean and introducing more diversified and sustainable tourism economies that can 37 better withstand external shocks such as disruptions and loss of markets from COVID-19 (Sheller, 2021). In 38 the Seychelles, various government and tourism industry initiatives are focused on the promotion of 39 sustainable tourism ventures that lower emissions, protect and promote biodiversity conservation (e.g. new 40 marine protected areas with mitigation and adaptation benefits), and are climate resilient (Robinson et al., 41 2021). In 2016 the Seychelles signed the world's first nature-for-debt swap wherein an NGO (The Nature 42 Conservancy) agreed to pay off Seychelles' public debt to the Paris Club (foreign creditors) in return for the 43 Seychelles government establishing marine conservation areas (Silver and Campbell, 2018). | Heritage | 3125 - 3125 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 44 45 One key area where enhanced climate risk integration is critical is infrastructure-related decisions especially 46 on coastal areas (World Bank, 2017). However, despite increasing awareness of climate risks and 47 experienced impacts, decisions on for example infrastructure locations still reflect cultural preferences. For 48 example, Hay et al. (2019) report that despite recommendations to relocate the redevelopment site of the 49 Parliamentary Complex in Samoa away from the coast, multiple cultural and historical factors influenced the 50 decisions to redevelop at the original site. In the Solomon Islands, however, emerging evidence suggests that 51 adaptation efforts to enhance the resilience of infrastructure are also serving to help urban areas address 52 problems associated with rapid urbanization and provide new opportunities for sustainable development 53 (Robinson et al., 2021). | Heritage | 3125 - 3125 |
| IPCC | IPCC_AR6_WGII_Full_ Report | conditions; X barrier and potential maladaptation) ES P R S C Agroforestry (Table 2.7; Table 5.ES; Chapter 5.10.4; Chapter 5.12.5.2; Box 5.10; Table 16.2) - Climate Adaptation and Maladaptation in Cocoa and Coffee Production (Box 5.7) Food provision & Fuel (wood) provision, carbon sequestration, biodiversity and ecosystem conservation, diversification and improved economic incomes, water and soil conservation, and aesthetics + Secure tenure arrangements, supporting Indigenous knowledge, inclusive networks and socio-cultural values, access to information and management skill X Higher water demand; disruption of hydrology; loss of native biodiversity; reduced resilience of certain plants; degraded soil and water quality; improper and increased use of agrochemicals, pesticides, and fertilizers *** ** ** Forest maintenance and restoration (Box 2.2; Table 16.2; Table Cross�Chapter Box NATURAL.1 in Chapter 2) - Protected area planning in Thailand (Chapter 2.6.5.3) - Conserving Joshua trees in the Joshua National Park (Chapter 2.6.5.6) - Addressing Vulnerability of Peat Swamp Forests in South East Asia (Chapter 2.6.5.10) - Reduce emissions from deforestation and forest degradation (REDD+) (Chapter 5.6.3.3; Table 16.2) Ecosystem conservation & Food provision, fuel provision, job creation, carbon sequestration, biodiversity conservation, air quality regulation, water and soil conservation, vector-borne disease control, improved mental health, cultural benefits, natural resources relative conflict prevention + Cooperation of indigenous peoples and other local communities X Planting large scale non-native monocultures leads to loss of biodiversity and poor climate change resilience, increased vulnerability to landslide, increased sensitivity of new tree species, reduced resilience of certain plants, high water demand, trees planted damaged buildings during heavy storms, lack of carbon rights in national legislations ** ** *** ** Traditional practices/indigenous knowledge and local knowledge (IKLK) (Table 2.7; Chapter 5.6.3; Chapter 5.14.2.2; Table 16.2) - Crop and livestock farmers on observed changes in climate in the Sahel (Box 5.6) Food and material provision & Carbon sequestration + Partnerships between key stakeholders such as researchers, forest managers, and local actors, indigenous and local knowledge *** ** ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 18 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 18-52 Total pages: 197 - Karuk Tribe in northern California (Chapter 5.6.3.2) Restoring natural fire regimes (Table 2.7) - Protecting Gondwanan wildfire refugia in Tasmania, Australia (Chapter 2.6.5.8) Fire regulation & Biodiversity conservation *** Natural flood risk management (Table 2.7) - Natural Flood Management (NFM) in England, United Kingdom (Chapter 2.6.5.2) Water security, flood regulation, sediment retention & Biodiversity and ecosystem conservation *** ** Coastal ecosystem conservation (Table Cross-Chapter Box NATURAL.1 in Chapter 2) (Table 16.2)(Table 2.7) - African penguin on-site adaptation (Chapter 2.6.5.5) Coastal protection against sea level rise and storm surges & Fisheries, carbon sequestration, biodiversity and ecosystem conservation, flood regulation, water purification, recreation, and cultural benefits X NH4 emissions, digging channels and sand walls around homes, loss of recreational value of beaches, shifted the flood impacts to poor informal urban settlers, erosion and degraded coastal lands ** *** ** Eco-tourism within protected areas (Table 2.7) Tourism & Habitat protection *** ** Aquaculture (Chapter 5.9.4; Table 16.2; Table Cross-Chapter Box NATURAL.1 in Chapter 2) Food provision & Biodiversity conservation + Farmer incentives, participatory adaptation to context X Lack of financial, technical or institutional capacity; short value chains; productivity varies by system; over�fertilizing; deforestation of mangroves; salt intrusion; increased flood vulnerability *** * Water-energy-food (WEF) nexus (Box 4.7) - Food Water Energy Nexus in Asia (Chapter 10.6.3) - New Zealand's Land, Water and People Nexus under a changing climate (Box 11.7) Water, energy, and food provision X Insufficient data, information, and knowledge in understanding the WEF inter-linkages; lack of systematic tools to address trade-offs involved in the nexus *** Urban greening (Table 2.7; table 16.2; Table Cross-Chapter Box NATURAL.1 in Chapter 2) - Ecosystem based adaptation in Durban, South Africa (Chapter 2.6.5.7) Urban flood management, water savings, urban heat island mitigation & Reduced carbon emissions, air and noise regulation, improved mental health, energy savings, recreation, and aesthetics + Meaningful partnerships, | Heritage | 3146 - 3148 |

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| IPCC | IPCC_AR6_WGII_Full_Report | 53 54 Focusing on bottom-up and community-led transformations, there is emphasis on the role of grassroots 55 organizations in transformations. Community actions around specific locations or topics have parallels to the 56 idea of transformative spaces. They are sites of innovative activity (Seyfang and Smith, 2007). Grassroots 57 organizations can bridge the local and the political scales by politicizing actors and creating new interactions ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 18 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 18-55 Total pages: 197 1 between individuals and political processes (Novák, 2021). They are a collective approach to pushing for 2 both individual and societal change (Sage et al., 2021). | Heritage | 3149 - 3150 |
| IPCC | IPCC_AR6_WGII_Full_Report | 52 53 54 18.4 Agency and Empowerment for Climate Resilient Development 55 56 As reflected in the discussion of societal transitions (18.3), people and their values and choices play an 57 instrumental role in CRD. The agency of people to act on CRD is grounded in their worldviews, beliefs, ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 18 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 18-65 Total pages: 197 1 values, and consciousness (Woiwode, 2020) and is shaped through social and political processes including 2 how policies and decision-making recognize the voices, knowledges and rights of particular actors over 3 others (very high confidence) (Harris and Clarke, 2017; Nightingale, 2017; Bond and Barth, 2020; Muok et 4 al., 2021). Since the AR5, evidence on diverse forms of engagement by and among social, political and 5 economic actors to support climate resilient development and sustainability outcomes, has increased. New 6 forms of decision-making and engagement are emerging within the formal policy making and planning 7 sphere, including co-production of knowledge, interventions grounded in the arts and humanities, civil 8 participation and partnerships with business (Ziervogel et al., 2016a; Roberts et al., 2020). In addition, the 9 set of actors that drive climate and development actions are recognized to extend beyond government and 10 formal policy actors to include civil society, education, industry, media, science and art (Ojwang et al., 2017; 11 Solecki et al., 2018; Heinrichs, 2020; Omukuti, 2020). This makes the power dynamics among actors and 12 institutions critical for understanding the role of actors in CRD (Buggy and McNamara, 2016; Camargo and 13 Ojeda, 2017; Silva Rodríguez de San Miguel, 2018). | Heritage | 3159 - 3160 |
| IPCC | IPCC_AR6_WGII_Full_Report | 7 8 One output from systems of governance is formal policy frameworks and policies that influence processes 9 and outcomes of system transitions that support CRD (18.1.3). The Paris Agreement, for example, provides a 10 framework for CRD by defining a mitigation-centric goal of 'limiting warming to well below 2°C and 11 enabling a transition to 1.5°C' (UNFCCC, 2015). It also provides for a broadly defined global adaptation 12 goal (UNFCCC, 2015: Art. 7.1). The Nationally Determined Contributions (NDCs) are the core mechanism 13 for achieving and enhancing climate ambitions under the Paris Agreement. However, the pursuit of a given 14 NDC within a specific country will likely necessitate a range of other policy interventions that have more 15 immediate impact on technologies and behavior, implicating transitions in energy, industry, land, and 16 infrastructure (very high confidence (18.3.1). SDG-relevant activities are increasingly incorporated into 17 climate commitments in the NDCs (at last count 94 NDCs also addressed SDGs), contributing to several 18 (154 out of the 169) SDG targets (Brandi and Dzebo; Pauw et al., 2018). This reflects the potential of the 19 NDCs as near-term policy instruments and sign-posts for progress toward CRD (medium agreement, limited 20 evidence) (McCollum et al., 2018b). | Heritage | 3162 - 3162 |
| IPCC | IPCC_AR6_WGII_Full_Report | 54 55 [END BOX 18.7 HERE] 56 57 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 18 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 18-71 Total pages: 197 1 18.4.2.3 Institutional capacity 2 3 Institutional capacity for system transitions refers to the capacity of structures and processes, rules, norms, 4 and cultures to shape development expectations and actions aimed at durable improvements in human well- 5 being. The AR5 highlighted the need for strong institutions to create enabling environments for adaptation 6 and greenhouse gas mitigation action (Denton et al., 2014). Institutions stand within the social and political 7 practices and broader systems of governance that ultimately drive adaptation and development processes and 8 outcomes. They are thus produced by them and can become tools by which some actors constrain the actions 9 of others (Gebreyes, 2018). As a consequence, they and can become a significant barrier to change, whether 10 incremental or more transformational (very high confidence). The post-AR5 focus on transformational 11 adaptation and resilience present in the literature suggests that institutions that enable system transitions 12 toward CRD are secure enough to facilitate a wide range of voices, and legitimate enough to change goals or 13 processes over time, without reducing confidence in their efficacy. | Heritage | 3165 - 3166 |
| IPCC | IPCC_AR6_WGII_Full_Report | 57 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 18 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 18-73 Total pages: 197 1 For example, political arenas range from formalized election and voting procedures to more informal and 2 less transparent practices, like special interest lobbying. Town squares and streets can become sites of 3 political struggle and dissent, including protests against climate inaction. As a more specific case-in-point, 4 the formal space for national, sub-national and international adaptation governance emerged at COP 16 5 (UNFCCC, 2010) when adaptation was recognized as having a similar level of priority as mitigation. The 6 Paris Agreement (UNFCCC, 2015) built on this and the 2030 Sustainable Development Agenda (United 7 Nations, 2015) to link adaptation to development and climate justice, widening the scope of adaptation 8 governance beyond formal government institutions. It also highlighted the importance of multi-level 9 adaptation governance, including non-state voices from civil society and the private sector. This implied the 10 need for wider arenas and modes of engagement around adaptation (Chung Tiam Fook, 2017; Lesnikowski 11 et al., 2017; IPCC, 2018a) that facilitate coordination and convergence among these diverse actors including 12 individual citizens to collectively solve problems and unlock the synergies between adaptation and 13 mitigation and sustainable development (IPCC, 2018a; Romero-Lankao et al., 2018). | Heritage | 3167 - 3168 |

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| Organisation | Document | Quotation Content | Codes | Page |
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| IPCC | IPCC_AR6_WGII_Full_ Report | 54 55 To address these difficult contests, climate- and global environmental change-related worldviews are often 56 scientized. This can exclude other worldviews which ultimately narrows understanding of climate change 57 and the solution space. Hence, the post-AR5 literature on worldviews focuses on the numerous meanings, ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 18 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 18-74 Total pages: 197 1 associations, narratives and frames of climate change and how these shape perceptions, attitudes and values 2 (Morton, 2013; Boulton, 2016; Hulme, 2018; Nightingale Böhler, 2019). The recognition of the diversity of 3 interpretations and meanings has led to multidisciplinary and transdisciplinary research that incorporates the 4 humanities and the arts (Murphy, 2011; Elliott and Cullis, 2017; Steelman et al., 2019; Tauginienė et al., 5 2020), feminist studies (MacGregor, 2003; Demeritt et al., 2011; Bell, 2013; Brink and Wamsler, 2019; 6 Plesa, 2019) and religious studies (Sachdeva, 2016; McPhetres and Zuckerman, 2018) to examine diverse 7 understandings of reality and knowledge possibilities around climate change. In addition, literature on 8 cultural cognition, epistemological plurality and relational ontologies draws on non-Western worldviews and 9 forms of knowledge (Goldman et al., 2018) (Jackson, 2016; Nightingale, 2016; Xue et al., 2016). | Heritage | 3168 - 3169 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 19 20 21 [START CROSS-CHAPTER BOX INDIG HERE] 22 23 Cross-Chapter Box INDIG: The Role of Indigenous Knowledge and Local Knowledge in 24 Understanding and Adapting to Climate Change 25 26 Authors: Tero Mustonen (Finland), Sherilee Harper (Canada), Gretta Pecl (Australia), Vanesa Castán Broto 27 (Spain), Nina Lansbury (Australia), Andrew Okem (Nigeria/South Africa), Ayansina Ayanlade (Nigeria), 28 Jackie Dawson (Canada), Pauline Harris (Aotearoa-New Zealand), Pauliina Feodoroff (Finland), Deborah 29 McGregor (Canada) 30 31 Indigenous knowledge refers to the understandings, skills and philosophies developed by societies with long 32 histories of interaction with their natural surroundings (UNESCO, 2018; IPCC, 2019a). Local knowledge 33 refers to the understandings and skills developed by individuals and populations, specific to the places where 34 they live (UNESCO, 2018; IPCC, 2019a). Indigenous knowledge and local knowledge are inherently 35 valuable but have only recently begun to be appreciated and in western scientific assessment processes in 36 their own right (Ford et al., 2016). In the past these often endangered ways of knowing have been suppressed 37 or attacked (Mustonen, 2014). Yet these knowledge systems represent a range of cultural practices, wisdom, 38 traditions, and ways of knowing the world that provide accurate and useful climate change information, 39 observations, and solutions (very high confidence) (Table Cross-Chapter Box INDIG.1). Rooted in their own 40 contextual and relative embedded locations, some of these knowledges represent unbroken engagement with 41 the earth, nature and weather for many tens of thousands of years, with an understanding of the ecosystem 42 and climatic changes over longer-term timescales that is held both as knowledge by Indigenous Peoples and 43 Local Peoples as well as in the archaeological record (Barnhardt and Angayuqaq, 2005; UNESCO, 2018). | Heritage | 3169 - 3169 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 8 9 Multiple knowledge systems and frameworks 10 11 Indigenous knowledge systems include not only the specific narratives and practices to make sense of the 12 world, but also profound sources of ethics and wisdom. They are networks of actors and institutions that 13 organise the production, transfer and use of knowledge (Löfmarck and Lidskog, 2017). There is a pluralism 14 of forms of knowledge that emerge from oral traditions, local engagement with multiple spaces, and 15 Indigenous cultures (Peterson et al., 2018). Recognising such multiplicity of forms of knowledge has long 16 been an important concern within sustainability science (Folke et al., 2016). Less dominant forms of 17 knowledge should not be put aside because they are not comparable or complementary with scientific 18 knowledge (Brattland and Mustonen, 2018; Mustonen, 2018; Ford et al., 2020; Ogar et al., 2020). Instead, 19 Indigenous knowledge and local knowledge can shape how climate change risk is understood and 20 experienced, the possibility of developing climate change solutions grounded in place-based experiences, 21 and the development of governance systems that match the expectations of different Indigenous knowledge 22 and local knowledge holders (very high confidence). | Heritage | 3170 - 3170 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 47 48 For climate research, the role of oral histories as a part of Indigenous knowledge and local knowledge is 49 extremely relevant. For example, ocean adaptation initiatives can be guided by oral historians and keepers of 50 knowledge who can convey new knowledge and baselines of ecosystem change over long-time frames 51 (Nunn and Reid, 2016). Oral histories can also convey cultural indicators and linguistic devices of species 52 identification as a part of a local dialect matrix and changes in ecosystems and species using interlinkages 53 not available to science (Mustonen, 2013; Frainer et al., 2020). Oral histories attached to maritime place 54 names, especially underwater areas (Brattland and Nilsen, 2011), can position observations relevant for 55 understanding climate change over long ecological timeframes (Nunn and Reid, 2016). Species abundances, 56 well-being and locations are some of the examples present in the ever-evolving oral histories as living ways 57 of knowing. Indigenous knowledge and oral histories may also have the potential to convey governance, ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 18 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 18-77 Total pages: 197 1 moral, and ethical frameworks of sustainable livelihoods and cultures (Mustonen and Shadrin, 2020) rooted 2 in the particular Indigenous or local contexts that are not otherwise available in written or published forms. | Heritage | 3171 - 3172 |
| IPCC | IPCC_AR6_WGII_Full_ Report | Latin America In Venezuela, Brazil, and Guyana, Indigenous knowledge systems have led to a lower incidence of wildfires, reducing the risk of rising temperatures and droughts (Mistry et al., 2016). The Mapuche Indigenous Peoples in Chile use various traditional and sustainable agricultural practices, including: native seed conservation and exchange (trafkintu), crop rotation, polyculture, and tree�crop association. They also give thanks to Mother Earth through rituals to nurture socioecological sustainability (Parraguez-Vergara et al., 2018). In rural Cusco Region of Peru, “cultures values known in Quechua as ayni (reciprocity), ayllu (collectiveness), yanantin (equilibrium) and chanincha (solidarity)” have led to successful adaptation to climate change (Walshe and Argumedo, 2016). | Heritage | 3173 - 3173 |

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| Organisation | Document | Quotation Content | Codes | Page |
|---|---|---|---|---|
| IPCC | IPCC_AR6_WGII_Full_ Report | 32 33 Subsidies 34 35 The World Bank has been encouraging both developed and developing states, especially those with petroleum 36 reserves, to use the removal of subsidies as a mechanism for promoting energy transitions away from fossil 37 fuels. The transition has led to social unrest in some cases, especially where there is a culture of entitlement to 38 low-cost energy because it is an indigenous resource. Such reforms have been more effective when 39 governments have been able to clearly show how savings are applied to social and health programs that benefit 40 human well-being. Nevertheless, policy makers should not underestimate the complexity of issues involved in 41 the removal of subsidies that will increase the cost of carbon and hasten the transition to cleaner fuels (Scobie, 42 2017; Scobie et al., 2018; Chen et al., 2020a). A crucial issue to take into account is the harmful effects some 43 subsidies have on biodiversity. Although governments agreed in 2010 to make progress on reducing subsidies 44 in 2010, by 2020 few governments had identified specific incentives to remove or taken action toward their 45 removal. Further investigation of the positive and negative effects of subsidy redirection or elimination on 46 people and the environment (Dempsey et al., 2020). | Heritage | 3178 - 3178 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 31 32 Prompted by SR1.5, new youth movements seek to use science-based policy to break with incremental 33 reforms and demand radical climate action beyond emissions reductions (Hallam, 2019; Klein, 2020; 34 Thackeray et al., 2020; Thew et al., 2020). Recent social movements and climate protests embrace new 35 modalities of action related to political responsibility for climate injustice through disruptive collective 36 political action (Young, 2003; Langlois, 2014). This is complemented by a regenerative culture and ethics of 37 care (Westwell and Bunting, 2020). These new social movements are based on nonviolent methods of 38 resistance, including actions classified as dutiful, disruptive and dangerous dissent (O'Brien, 2018). | Heritage | 3180 - 3180 |
| IPCC | IPCC_AR6_WGII_Full_ Report | financial challenges in programming and implementing activities to support concrete adaptation measures (9.14.5) • high debt levels exacerbate fiscal challenges and undermine economic resilience (9.14) • insufficient development and adaptation finance and accessibility of finance (9.14.5) • complexity of estimating the costs and benefits for adaptation measures in specific contexts (9.14.2) • exclusions of migrants and other vulnerable populations from social programs (9.9.4) • mismatch between the supply of, and demand for, climate services (9.5) • climate change literacy can enable the mainstreaming of climate change into national and sub-national developmental agendas (9.4.2) • Adaptive responses can be used as an opportunity for comprehensive, transformative change (9.6.2) • Investments in human capital, can facilitate socioeconomic development and poverty reduction (9.9.1) • Strengthening the participation of women in decision-making as well as advance traditional and local knowledge can support climate action and sustainable livelihoods (9.9.3) • strengthening climate services (9.4.2) • ecosystem based adaptation (9.11.4.2) • economic diversification (9.12.3) • intensive irrigation9.15.2 • agricultural and livelihood diversification (9.12.3) • drought resistant crop varieties (9.15.2) • soil and water conservation (9.15.2 • (T) competing uses for water such as hydropower generation, irrigation, and ecosystem requirements create trade-offs among different management objectives (9.7.3) • (T) migration in response to unfavorable environmental conditions provides opportunities for farmers but puts pressure on the provision of social services and reduces farm labor (9.15.2) • (T) intensive Irrigation contributes to the development of agriculture but has come at a cost to ecosystem integrity and human well-being (9.15.2) GINI 42.8 (27.6- 63.4) FRAGILITY 87.3 (57.0- 110.9) CO2/PC 1.1 (0.0-8.1) Asia HPAHDI 0.65 (0.47- 0.78) • migration and displacement (Box 10.6) • uneven economic development (10.4.6) • rapid land use change (10.4.6) • Investing in climate-resilient and sustainable infrastructure can be a source of green jobs as well as a means of reducing climate vulnerability (10.6.2) • risk insurance 10.5.5 • climate-smart agriculture 10.4.5.5, (Table 10.6) • wetland protection and restoration (Table 10.6) • (S+) nature-based adaptation solutions, wetland protection, and climate-smart agriculture enhance carbon sequestration GINI (Table 10.6) 34.9 (26.6- 43.9) FRAGILITY 73.6 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 18 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 18-94 Total pages: 197 (32.3- 111.7) • increasing inequality (10.4.6) • large, socially differentiated vulnerable populations (10.4.6) • sustainable development pathways that connect climate change adaptation and disaster risk reduction efforts can reduce climate vulnerability and increase resilience (10.6.2) • social protection programs can develop risk management strategies to address loss and damage from climate change (10.5.6) • aquifer storage and recovery (Table 10.6) • integrated smart water grids (Table 10.6) • disaster risk management (Table 10.6) • early warning systems (Table 10.6) • resettlement and migration (Table 10.6) • nature-based solutions in urban areas • coastal green infrastructure (Table 10.6) • (S+) disaster risk reduction and capacity building has synergistic interactions with climate adaptation when the two are effectively integrated (10.6.2) • (S+) environmental sustainability has benefits for relieving poverty and promoting social equity (10.6.4) • (T) intensive irrigation and other forms of water consumption can have a negative effect on water quality and aquatic ecosystems (10.6.3) CO2/PC 6.3 (0.3-38.0) Australasia PPAHDI 0.75 (0.70- 0.81) • Underinvestment in adaptation, particularly in public health systems, given current and projected risks (11.3.6.3) • Underlying social and economic vulnerabilities exacerbate disadvantage among particular social groups (11.8.2) • Competing policy and planning objectives within governments (11.7.2) • Limits to adaptation across the region and among neighbors (11.7.2) • Fear of litigation and demands for compensation create disincentives for climate adaptation (11.7.2) • different climate change risk perceptions among different groups (11.7.2) • implementation of national policies and guidance on climate adaptation and resilience (Box 11.5) • cooperation among individual farmers for adaptation and regional innovation (11.7.1) • enhancing understanding of Indigenous knowledge and practices (Table 11.11) • climate adaptation services, planning and tools from government and private | Heritage | 3188 - 3191 |

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| Organisation | Document | Quotation Content | Codes | Page |
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| IPCC | IPCC_AR6_WGII_Full_Report | • increase efficiency and equity of water management and allocation (14.4.3.3) • energy conservation measures (14.6.1.3) • guidelines, codes, standards, and specifications for infrastructure (14.6.1.6) • modifying zoning and buying properties in floodplains (14.6.1.3) • web-based tools for visualizing and exploring climate information scenario planning and risk analyses (s14.6.1.6) • (S+) Post-fire ecosystem recovery measures, restoration of habitat connectivity, and managing for carbon storage enhance adaptation potential and offers co-benefits with carbon mitigation (Box 14.1) • (T) REDD+ represents a trade-off between carbon mitigation and the ability of communities to improve their food security (14.4.7) • (T) New coastal and alpine developments generate economic activity but enhance local social inequalities (15.4.10) GINI 40.0 (33.3- 45.4) FRAGILITY 45.4 (21.7- 69.9) CO2/PC 11.9 (3.8-16.6) Small Islands PPAHDI 0.68 (0.51- 0.76) • high dependence of economic activity on tourism (15.3.4.5) • Lack of coordination among government departments (15.6.1) • limited regional cooperation (15.6.1) • increasing women's access to climate change funding and support from organizations (15.6.5)promoting agroecology, food sovereignty, and regenerative economies (15.7) • raising dwellings and other infrastructure (15.5.2) • land reclamation (15.5.2) • migration and planned resettlement (15.5.2) • ecosystem-based adaptation including Indigenous and local knowledge (15.5.2) • (S+) development decisions and outcomes are strengthened by consideration of climate and disaster risk (15.7) • (S-) impacts of invasive alien species on islands are projected to increase with GINI 40.2 (28.7- 56.3) FRAGILITY 64.6 (38.1- 97.5) ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 18 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 18-97 Total pages: 197 CO2/PC 3.7 (0.3-31.3) • absence of planning frameworks (15.6.1) • corruption and corrupt people in political and public life (15.6.1) • insufficient human capital (15.6.1) • competing development priorities (15.5.5) • lack of education and awareness around climate change (15.6.4) • failure of externally driven adaptation (15.6.5) • constraints on economic, legislative, and technical capacity of local governments (15.7) • expanding sustainable tourism economies (15.7) • integrating climate change and disaster management with broader development planning and implementation (15.7) • using climate risk insurance as a way to support development and adaptation processes (15.7) • improving cross sectoral and cross agency coordination (15.7) • enhanced integration between development assistance, public financial management, and climate finance (15.5.7) • protected areas (15.5.2) • ecosystem restoration and improved agroforestry practices (15.5.2 15.5.4) • community-based adaptation (15.5.5) • livelihood diversification and use of improved technologies and equipment (15.5.6) • diversifying cropping patterns, expanding or prioritizing other cash crops (15.5.6) • small-scale livestock husbandry (15.5.6) • irrigation technologies (15.5.6) • diversification away from coastal tourism • disaster risk management (DRM) (15.5.7) • early warning systems and climate services (15.5.7) time due to synergies between climate change and other drivers (15.3.3) • (S-) synergies between changing climate and other natural and anthropogenic stressors could lead to disproportionate impacts on biodiversity (15.3.3) 1 2 3 Table 18.7: Sectoral synthesis of dimensions of climate-resilient development. For each sectoral chapter of the WGII report, this table identifies those SDGs that are discussed in the 4 relevant chapter as being particularly relevant to the sector. In addition, the table contains evidence of sustainable development challenges and opportunities as well as 5 adaptation/sustainable development options and potential synergies and trade-offs associated with their implementation. Synergies and trade-offs are categorized as follows: (T) 6 Trade-off among policies and practices; (S+) Synergy among policies and practices that enhances sustainability; (S-) Synergy among policies and practices that undermines 7 sustainability. | Heritage | 3191 - 3192 |

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| Organisation | Document | Quotation Content | Codes | Page |
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| IPCC | IPCC_AR6_WGII_Full_Report | and knock-on effects related to civil unrest (BIOECO.1) Cities, settlements and key infrastructure SDG11, SDG13, SDG17 • poor municipal funding, data collection, and collaboration hinders sustainable development initiatives, capacity building, and climate action (6.1.5, 6.4.5, 6.4.9) • high urbanization rates pose challenges to areas that already have high levels of poverty, unemployment, informality, and housing and service backlogs (6.2.1) • Limited capacity for early�warning systems in low-income countries (6.3.2) • lack of administrative capacities, coordination across sectors and efforts, transparency and accountability slows sustainability transitions and disaster risk reduction (Case Study 6.4) • urban ecological infrastructure including green, blue, turquoise and others can be a source of nature-based solutions that can improve both adaptation and mitigation in urban areas (6.1.2) • transition architecture movements can drive urban adaptation (6.4.1) • transformative capacities support adaptation efforts and systemic change processes (6.4.4) • incorporating Indigenous and local knowledge help generate more people-oriented and place�specific adaptation policies (6.4.7) • climate finance offers the opportunity to overcome structural impediments to climate action (Box 6.5) • green infrastructure, sustainable land use and planning, and sustainable water management (6.1.2) • nature-based solutions (6.3.3) • insurance (6.3.2) • switching to air cooling for thermal power plants (6.3.4) • increasing the efficiency of hydro and thermoelectric power plants (6.3.4) • changing reservoir operation rules (6.3.4) • upgrading infrastructure and strengthening, or relocating (critical) assets (6.3.4) • including green, blue, turquoise and nature-based solutions (Cross-Chapter Box URBAN in Chapter 6) • (S+) sustainable urban energy planning that includes opportunities to avoid and reduce the UHI effect can provide synergies for both climate mitigation and adaptation in urban areas (Cross-Chapter Box URBAN in Chapter 6) • (S+) natural ventilation and passive energy strategies can capture synergies between climate mitigation and adaptation (Cross�Chapter Box URBAN in Chapter 6) • (S+) community-based adaptation has potential to be better integrated to enhance well-being and create synergies with the Sustainable Development Goals • (T) urban mitigation efforts can create trade-offs with adaptation such as intensifying the Urban ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Chapter 18 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 18-101 Total pages: 197 • urban ecological infrastructure can be a source of nature-based solutions that can improve both adaptation and mitigation in urban areas (Cross-Chapter Box URBAN in Chapter 6) • high density environments coupled with other design measures can provide mitigation and adaptation benefits (Cross�Chapter Box URBAN in Chapter 6) • cooling networks (Cross�Chapter Box URBAN in Chapter 6) • early warning systems (Table 6.4) • resource demand and supply side management strategies (Table 6.4) • enhanced monitoring of air quality in rapidly developing cities (Table 6.4) • investment in air pollution controls (Table 6.4) • core and shell preservation, elevation and relocation for heritage buildings (6.3.2) Heat Island (UHI) effect (Cross�Chapter Box URBAN in Chapter 6) • (T) efforts aimed at increasing adaptation may undermine mitigation objectives by increasing investment in hard infrastructure that increases emissions (Cross�Chapter Box URBAN in Chapter 6) • (T) lack of open and green spaces may induce long-distance leisure trips thereby increasing emissions and (Cross-Chapter Box URBAN in Chapter 6) Health, wellbeing and the changing structure of communities SDG3, SDG5, SDG8, SDG10, SDG13 • a lack of capacity for adaptation has resulted in only moderate or low levels of adaptation implementation across different countries (7.4.2) • transitioning to renewable energy sources presents opportunities for realizing health co-benefits (7.4.4) • shifting to healthier plant-rich diets can reduce GHG emissions and reduce land-use (Cross�Chapter Box HEALTH in Chapter 7) • future flows of migration within and between countries are likely to respond strongly to particular combinations of climatic hazards and may present challenges for future adaptation policies and programs • climate change disruptions to natural environments can be expected to disrupt livelihood practices, stimulate higher rates • COVID-19 recovery investments offer an opportunity to contribute to climate resilient development through a green, resilient, | Heritage | 3195 - 3199 |
| IPCC | IPCC_AR6_WGII_Full_Report | 13 14 The more recent literature adds significant context to the concept of CRD, but also introduces broader 15 perspectives regarding its significance in the arena of climate action. Hence, concepts that are both 16 complementary to, and competitive with, CRD, such as climate safe', 'climate compatible' and 'climate 17 smart' development (Huxham et al., 2015; Kim et al., 2017b; Ficklin et al., 2018; Mcleod et al., 2019) 18 (18.1.1). These different framings of the intersection between sustainable development and climate action 19 are used in different communities of research and practice, which complicates efforts to provide clear 20 guidance to decision-makers regarding the goals of CRD and how best to achieve it. This is attributable in 21 part to persistent conceptual confusion and disciplinary divides over more fundamental concepts such as 22 resilience and sustainability (Rogers et al., 2020; Zaman, 2021), not to mention contested perspectives 23 regarding development (Lo et al., 2020; Song et al., 2020a; Morton, 2021) (medium agreement; medium 24 evidence). | Heritage | 3199 - 3199 |
| IPCC | IPCC_AR6_WGII_Full_Report | 33 34 In this way, recent social movements and climate protests show new modalities of action related to political 35 responsibility for inaction based on contestation. The new climate movement led mostly by youngsters, 36 markedly seek science-based policy and more importantly, demand to break with a reformist stance and 37 social inertia through radical climate action. This is mostly done through collective disruptive action, and 38 non-violent resistance to promote awareness, a regenerative culture and ethics of care. These movements 39 have resulted in notable political successes, such as declarations of climate emergency at the national and 40 local level, as well as in universities. Also, their methods have proven effective to end fossil fuel 41 sponsorship. | Heritage | 3203 - 3203 |
| IPCC | IPCC_AR6_WGII_Full_Report | 24 25 CCB FEASIB.3.2.2 Sustainable aquaculture 26 There is medium evidence with medium agreement on the feasibility of sustainable aquaculture as an 27 adaptation measure. Sustainable aquaculture (e.g. Integrated Multi-Tropic Aquaculture, polyculture, 28 aquaponics, mangrove-integrated culture) can have socio-economic benefits for vulnerable communities and 29 small-scale fisheries (Ahmed, 2018; Blasiak et al., 2019; Mustafa et al., 2021; Thomas et al., 2021; Xuan et 30 al., 2021). Nevertheless, caution is important to guarantee that access to fish supply of local and vulnerable 31 communities is not affected (Chan et al., 2019; Galappaththi et al., 2020). Access to financial resources is 32 often a barrier to implementation, although sustainable aquaculture can increase employment opportunities 33 that are increasingly gender equitable (Alleway et al., 2018; Leakhena et al., 2018; Valenti et al., 2018; 34 Gopal et al., 2020), as well as increasing the resilience of coastal livelihoods to climate change (Shaffril et 35 al., 2017; Blasiak and Wabnitz, 2018). Technological, institutional and socio-cultural factors can form 36 barriers to the feasibility of sustainability of aquaculture (e.g. (Ahmed et al., 2018; Blasiak et al., 2019; 37 Galappaththi et al., 2019; Boyd et al., 2020; Osmundsen et al., 2020; Stentiford et al., 2020; Mustapha et al., 38 2021; Xuan et al., 2021). | Heritage | 3255 - 3255 |

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| Organisation | Document | Quotation Content | Codes | Page |
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| IPCC | IPCC_AR6_WGII_Full_ Report | 55 Sustainable agriculture is likely to receive strong support from many countries but may experience resistance 56 for several reasons (e.g., competition with existing industries, debates over tolerance to aesthetic changes to 57 coastlines). Literature on this area is growing and potential barriers at the government and political levels are ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Chapter 18 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute 18-161 Total pages: 197 1 significant (e.g. (Jayanthi et al., 2018; Blasiak et al., 2019; Hargan et al., 2020; Osmundsen et al., 2020; 2 Stentiford et al., 2020; Mustafa et al., 2021; Qurani et al., 2021). | Heritage | 3255 - 3256 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 14 15 Diverse socio-economic co-benefits have been identified, including integration of tourism activities, 16 increased educational opportunities for the reduction in storm damage, maintenance of ecosystems and their 17 services, increasing adaptive capacities of institutions (Romañach et al., 2018; Mestanza-Ramón et al., 2019; 18 Morris et al., 2019; Donatti et al., 2020; Ellison et al., 2020; Erftemeijer et al., 2020; Gómez Martín et al., 19 2020; Hanley et al., 2020a; Jones et al., 2020b; Martuti et al., 2020; Perera-Valderrama et al., 2020; Telave 20 and Chandankar, 2021); as well as environmental and geophysical co-benefits aspects, including mitigation 21 potential and hazard risk reduction (Propato et al., 2018; Romañach et al., 2018; Ellison et al., 2020; 22 Erftemeijer et al., 2020; Hanley et al., 2020a; Jones et al., 2020b; Martuti et al., 2020; Cantasano et al., 23 2021). | Heritage | 3256 - 3256 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 30 31 CCB FEASIB.3.2.6 Biodiversity management and ecosystem connectivity 32 There is robust evidence and medium agreement supporting the overall feasibility of biodiversity 33 management and ecosystem connectivity as adaptation options. With respect to its economic feasibility, 34 financial constraints continue to hinder broader implementation of biodiversity-based solutions (Lausche et 35 al., 2013; Chausson et al., 2020; Jones et al., 2020a).(Seddon et al., 2020a) highlights that only five percent 36 of climate finance goes towards adaptation strategies, and only one percent is destined to disaster risk 37 management including nature-based solutions and biodiversity management. Government support via 38 subsidies and fiscal transfers is critical for broader biodiversity management interventions. In addition, 39 REDD+ initiatives have been promoted as a profitable mechanism to advance biodiversity conservation 40 strategies while reducing carbon emissions. As far as ecosystem connectivity is concerned, its feasibility will 41 strongly depend on the existence of a regulatory framework that appropriately balances property rights, 42 environmental regulations and monetary incentives to ensure landowners' willingness to participate and 43 maintain ecosystem corridors (Jones et al., 2020b). The demands of commodity-based economies, favouring 44 extractive land-uses, present serious barriers to upscaling biodiversity-based adaptation interventions 45 (Seddon et al., 2020a). In addition, integrated assessments have shown how biodiversity-based solutions can 46 deliver jobs from landscape restoration or income from wildlife tourism and how those benefits are fairly 47 distributed (Chausson et al., 2020). | Heritage | 3258 - 3258 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 3 4 Several social co-benefits are found to follow from biodiversity management strategies, including improved 5 community health, recreational activities, eco-tourism, in addition to educational, spiritual and scientific 6 benefits (Lausche et al., 2013; Worboys et al., 2016; Seddon et al., 2020a). (Lavorel et al., 2020) show how 7 the benefits of biodiversity management are co-produced by harnessing ecological and social capital to 8 promote resilient ecosystems with high connectivity and functional diversity. Furthermore, (Chausson et al., 9 2020) note how properly implemented nature-based solutions, including biodiversity management, can 10 strengthen social networks and foster a sense of place, supporting virtuous cycles of community engagement 11 to sustain interventions over time. | Heritage | 3259 - 3259 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 35 36 CCB FEASIB.3.2.7 Improved cropland management 37 Improved cropland management, which includes agricultural adaptation strategies such as integrated soil 38 management, no/reduced tillage, conservation agriculture, planting of stress-resistant or early maturing crop 39 varieties, and mulching, has high economic and environmental feasibility (robust evidence, high agreement) 40 (AGEGNEHU and AMEDE, 2017; Lalani et al., 2017; Schulte et al., 2017; Thierfelder et al., 2017; Aryal et 41 al., 2018a; Mayer et al., 2018; Prestele et al., 2018; Sova et al., 2018; Gonzalez-Sanchez et al., 2019; 42 Lunduka et al., 2019; McFadden et al., 2019; Shah and Wu, 2019; TerAvest et al., 2019; Adams et al., 2020; 43 Aryal et al., 2020a; Debie, 2020; Mutuku et al., 2020; Somasundaram et al., 2020; Du et al., 2021). Despite 44 higher initial costs in some cases, the economic feasibility of improved cropland management is high 45 through improved productivity, higher net-returns, reduced input costs (Aryal, 2020 #6850}(Mottaleb et al., 46 2017; Keil et al., 2019; Lunduka et al., 2019; McFadden et al., 2019; Parihar et al., 2020). Self-efficacy is 47 shown to be the most important predictor in technical and non-technical adaptation behaviour (Zobeidi et al., 48 2021), while subsidies, extension services, training, commercial custom-hire services and strong social 49 connections such as farmer networks are among the factors supporting adoption among farmers (Section 50 8.5.2.3) (Aryal et al., 2015a; Aryal et al., 2015b; Kannan and Ramappa, 2017; Bedeke et al., 2019; Acevedo 51 et al., 2020). In some regions and for some practices, technological feasibility is constrained by cost, and 52 inadequate information and technical know-how on particular practices and their benefits and tradeoffs, 53 indicating medium feasibility (Khatri-Chhetri et al., 2016; Bhatta et al., 2017; Dougill et al., 2017; Kannan 54 and Ramappa, 2017; Aryal et al., 2018a; Sova et al., 2018; Findlater et al., 2019). Delays between actions 55 and tangible benefits can reduce public and private acceptability and uptake of improved cropland 56 management practices (e.g. (Dougill et al., 2017) in Malawi). | Heritage | 3259 - 3259 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 43 44 In Australia, climate change has been implicated in: drought-induced canopy dieback across a range of forest 45 and woodland types due to decades of declining rainfall in the southwestern hotspot (H133); fires in the 46 palaeo-endemic pencil pine forests (Tasmania H142); declines in vertebrates in the Australian Wet Tropics 47 World Heritage Area, which overlaps with the eastern part of the Northern Australia hotspot (H131), related 48 to warming and increased length of the dry season; and declines in grass and increases in shrubs in the 49 Bogong High Plains (high confidence) (Hoffmann et al., 2019). The Australian Alps have seen increased 50 species diversity following retreat of the snow line (Slatyer, 2010), replacement of long-lived trees by short- 51 lived shrubs following multiple wildfires (Zylstra, 2018), and changing ecological interactions due to 52 climate-related snow loss, drought and fires (high confidence) (Hoffmann et al., 2019). While warming is 53 allowing mangroves to expand their range in coastal hotspots of Asia and Australia (Ward et al., 2016; 54 Hughes et al., 2019a), drought and associated salinity stress has killed mangroves in northern Australia 55 hotspots (Chapter 11, Babcock et al., 2019). | Heritage | 3307 - 3307 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 53 54 Range expansions out of the Nansei Shoto (H231) hotspot south of Japan led to the replacement of temperate 55 kelp forests by tropical coral and herbivorous fishes on Japanese coasts (Kumagai et al., 2018). The Yellow 56 Sea (H230) is one of the most exploited marine hotspots, with decreasing ecosystem services compounded ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Cross-Chapter Paper 1 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP1-27 Total pages: 47 1 by climate change but low confidence for climate change contributing substantially to ecological degradation 2 (Wang et al., 2016; Song and Duan, 2019). | Heritage | 3318 - 3319 |
| IPCC | IPCC_AR6_WGII_Full_ Report | Actions Terrestrial Freshwater Marine Protect biodiversity hotspots Protect native forests, bush, and grasslands Stop pollution and sedimentation into streams, rivers, ponds, lakes Ban seabed trawling and dredging Control introduction and spread of invasive species and pests Increase connectivity Use riverbank and hedgerow corridors to connect protected native habitats Already connected Reduce habitat and species loss outside protected areas to add species dispersal (corridors) Outside biodiversity hotspots Environmentally sustainable agriculture, tourism, and other land and freshwater uses Environmentally sustainable aquaculture, fisheries, tourism Restoration and recovery Actively rehabilitate old mines, quarries and industrial lands Stabilise riverbanks. | Heritage | 3323 - 3323 |
| IPCC | IPCC_AR6_WGII_Full_ Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Cross Chapter Paper 2 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP2-6 Total pages: 42 1 2 CCP2.1.2 Urbanisation in Coastal Systems: Coastal City and Settlement Archetypes 3 4 This assessment uses an archetype framework categorizing coastal C&S according to geomorphological 5 characteristics, urban growth, economic resources, and inequalities (Figure CCP2.1). We use three broadly 6 defined coastal settlement geomorphologies in each row: open coasts (a coast with sediment without river 7 mouths), and two transitional coastal zones with river mouths: estuaries (a wetland receiving sediment from 8 both fluvial and marine sources, which is affected by tide, wave, and river processes), and deltas (a wetland 9 where fluvial sediment is supplied and deposited more rapidly than it can be redistributed by basin processes 10 such as waves and tides) (Bhattacharya, 1978; Barragán and de Andrés, 2015; Kay and Alder, 2017; 11 Haasnoot et al., 2019; Sterzel et al., 2020). Small island C&S are not singled out in this typology because 12 their coastlines often include the geomorphic features listed above, or require a different adaptation approach 13 at larger spatial scales (Haasnoot et al., 2019). Several coastal C&S have a combination of two typologies 14 e.g., Maputo-Matola, Mozambique, and Mumbai, India, having both open and transitional riverine coasts, 15 and can be classed as mixed. We also acknowledge several coastal C&S may have areas sited in 16 mountainous topography that abruptly rise from the coast (e.g., along the Mediterranean), but generally these 17 cities have narrow densely populated coastal shelfs exhibiting these three archetypal categories (Blackburn et 18 al., 2019). Arctic settlements are addressed separately in this CCP. | Heritage | 3344 - 3345 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 19 20 Coastal C&S within these geomorphological categories are further distinguished according to higher or 21 lower rates of urban growth and inequality – which can be estimated through population growth from 22 national census data, or areal extent of urban development (CEIC); as well as relative urban inequalities 23 estimated by Gini Coefficient data and urban-rural poverty rates (OECD, 2018; OECD, 2020). Combining 24 geomorphological and socio-economic data accounts for urban-rural interconnections and differences; with 25 levels of capital generation, diversity of economic functions and human development indices having 26 previously been used to discern cultural, economic, administrative and political differences between cities 27 and their hinterland (Blackburn et al., 2019; Rocle et al., 2020). For instance, the ecological, cultural and 28 economic footprint of tertiary sectors e.g., coastal tourism associated with the Australian Great Barrier Reef 29 stretches far beyond the nearest onshore settlement of Cairns (Bohnet and Pert, 2010; Brodie and Pearson, 30 2016). | Heritage | 3345 - 3345 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 30 31 32 Overall, interactions between climatic and non-climatic drivers of coastal change are increasing the 33 frequency and intensity of many coastal hazards, with settlement archetypes and the wider coastal zone 34 subject to escalating risk (high confidence) (Figure CCP2.2; Table SMCCP2.1 for examples of selected 35 coastal C&S). Risks can vary markedly between different archetypes. C&S sited on deltaic and estuarine 36 coasts face additional risks of pluvial flooding compared to open coasts; while greater vulnerabilities arise in 37 coastal settlements with higher inequalities. | Heritage | 3347 - 3347 |

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| IPCC | IPCC_AR6_WGII_Full_Report | 25 26 There is high confidence about regionally differentiated but considerable global sectoral impacts in coastal 27 C&S arising from exposure to hazards. Tangible impacts include damage, loss of life, loss of livelihoods, 28 especially fisheries and tourism (Tessler et al., 2015; Avelino et al., 2018; Hoegh-Guldberg et al., 2018; 29 Seekamp et al., 2019; Arabadzhyan et al., 2020); negative impacts on health and wellbeing, especially under 30 extreme events (McIver et al., 2016; Bakkensen and Mendelsohn, 2019; Bindoff et al., 2019; Pugatch, 2019); 31 and involuntary displacement and migration (Hauer, 2017; Davis et al., 2018; Neef et al., 2018; Boas et al., 32 2019; McLeman et al., 2021). Intangible impacts include psychological impacts due to extreme events, such 33 as heat-waves, flooding, droughts, and tropical cyclones; heightened inequality in coastal archetypes with 34 systematic gender/ethnicity/structural vulnerabilities; and loss of things of personal or cultural value, and 35 sense of place or connection, including existential risk of the demise of nations due to submergence (Allison 36 and Bassett, 2015; Barnett, 2017; Schmutter et al., 2017; Weir et al., 2017; Farbotko et al., 2020; Hauer et 37 al., 2020; Hoffmann et al., 2020; Bell et al., 2021). Impacts extend beyond the coastal zone, for example 38 disruption to ports and supply chains, with major geopolitical and economic ramifications from the C&S to 39 global scale (very high confidence) (Becker et al., 2018; Camus et al., 2019; Christodoulou et al., 2019; 40 Walsh et al., 2019; Hanson and Nicholls, 2020; Yang and Ge, 2020; Izaguirre et al., 2021; León-Mateos et 41 al., 2021; Ribeiro et al., 2021). | Heritage | 3348 - 3348 |
| IPCC | IPCC_AR6_WGII_Full_Report | 3 4 There is high confidence that loss of coastal ecosystem services will increase risks to all coastal C&S 5 archetypes that include reduced provisioning of materials and food (e.g., wood, fishery habitat) (Kok et al., 6 2021), amelioration of coastal hazards (e.g., attenuation of storm surges, waves, and containing erosion) 7 (Section 2.3.2.3; Godfroy et al., 2019; Schoutens et al., 2019; Zhu et al., 2020b), climate change mitigation 8 (through carbon sequestration) (Macreadie et al., 2017; Rovai et al., 2018; Ward, 2020), water quality 9 regulation (nutrient, pollutant and sediment retention and cycling) (Wilson et al., 2018; Zhao et al., 2018), 10 and recreation and tourism (Pueyo-Ros et al., 2018). | Heritage | 3349 - 3349 |
| IPCC | IPCC_AR6_WGII_Full_Report | 35 36 Retreat can effectively reduce the exposure of urban residents to coastal hazards and provide opportunity for 37 re-establishment of ecosystems services (very high confidence) (Song et al., 2018; Carey, 2020; Hindsley 38 and Yoskowitz, 2020; Lincke et al., 2020; Lincke and Hinkel, 2021). But there is high confidence that it can 39 sever cultural ties to the coast (Reimann et al., 2018) and can lead to negative and inequitable socio- 40 economic effects for resettled communities if not planned and implemented in ways that are inclusive, just 41 and address cultural, place-attachment and livelihood considerations (Ajibade, 2019; Adger et al., 2020; 42 Carey, 2020; Jain et al., 2021; Johnson et al., 2021), and the rights and practices of Indigenous People 43 (Nakashima et al., 2018; Ristroph, 2019; Mohamed Shaffril et al., 2020). If planned well ahead and aligned 44 with social goals, pathways to managed retreat can achieve positive outcomes and provide opportunities for 45 transformation of coastal C&S (Haasnoot et al., 2021a; Mach and Siders, 2021). There is medium confidence 46 that the availability of suitable and affordable land, and appropriate financing, is a major bottleneck for 47 planned relocation (Alexander et al., 2012; Ong et al., 2016; Hino et al., 2017; Fisher and Goodliffe, 2019; 48 Hanna et al., 2019; Buser, 2020; Doberstein et al., 2020), particularly in very dense mega-urban areas 49 (Ajibade, 2019) and crowded small islands (Neise and Revilla Diez, 2019; Weber et al., 2019; Kool et al., 50 2020; Lincke et al., 2020) 51 52 CCP2.3.6 Adaptation Pathways 53 54 No single adaptation intervention comprehensively addresses coastal risks and enables CRD. An adaptation 55 pathways approach can facilitate long-term thinking, foresee maladaptive consequences and lock-ins, and 56 address dynamic risk in the face of relentless and potentially high SLR; and frame adaptation as a series of 57 manageable steps over time (Cross-Chapter Box DEEP in Chapter 17; Figure CCP2.4; Haasnoot et al. | Heritage | 3353 - 3353 |
| IPCC | IPCC_AR6_WGII_Full_Report | 25 26 Even where BCR is high, finance may be inaccessible as it is challenging to convert the long-term benefits 27 of adaptation into the revenue streams that may be needed to initially finance adaptation investments (Hinkel 28 et al., 2018). For example, in Ho Chi Minh City, Vietnam, despite high BCR, high costs of flood protection 29 (US$1.4-2.6 billion) have prevented such adaptation measures from being implemented (Hinkel et al., 2018; 30 Cao et al., 2021). Moreover, drawing from places as distinct as small communities in Fiji (Neef et al., 2018) 31 and Belize (Karlsson and Hovelsrud, 2015), and megacities like New York City and Shanghai (Oppenheimer 32 et al., 2019), BCR provides only a limited view and consideration of feasibility, effectiveness, efficiency, 33 equity, culture, politics and power, and attachment to place, is more likely to foster CRD (high confidence). | Heritage | 3357 - 3357 |
| IPCC | IPCC_AR6_WGII_Full_Report | 41 42 Inclusive decision-making arrangements can enable participation, local ownership, and further equity in 43 crafting coastal adaptation plans and policies (Chu et al., 2016). Inclusion of diverse stakeholders can help 44 improve awareness of adaptation needs; help to bridge existing social inequalities in decision-making about 45 adaption needs, options and outcomes; close the gap between formal and informal institutions, and engage 46 Indigenous forms of decision-making, which often associate climate risks with livelihood, housing, and 47 employment stressors (Ziervogel et al., 2016; Fayombo, 2020). For example, research from Pacific Island 48 States (Nunn et al., 2017) and coastal Arctic zones (Romero Manrique et al., 2018) highlight the need to 49 engage with Indigenous environmental knowledge. Case studies from Indonesia, Philippines, and Timor- 50 Leste show that IKLK and customary laws can support environmental awareness, strengthen social cohesion, 51 and help communities to better respond to climate impacts (Hiwasaki et al., 2015). Research from coastal 52 Cambodia shows that inclusive governance arrangements can target empowerment of the most vulnerable 53 groups to facilitate better adaptation behavior and mainstream adaption knowledge through both formal and 54 informal education at the community level (Ung et al., 2016). | Heritage | 3358 - 3358 |

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| Organisation | Document | Quotation Content | Codes | Page |
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| IPCC | IPCC_AR6_WGII_Full_ Report | Cross-scale and cross-domain coordination: Coordination - Collaborative projects involve state and non-state actors Seychelles (0.1mill; open coast, small island): Cross-sectoral and institutional collaboration to improve use of limited financial resources; and ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Cross Chapter Paper 2 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP2-22 Total pages: 42 - Multi-lateral agreements, e.g., between neighbouring countries, coastal regions and C&S - Connect people, organizations and communities through boundary spanning organizations - Leadership by central actors with capable teams is key - Mobilise the capabilities of communities and non-state actors - Address policy inconsistencies and clarify roles and responsibilities - Secure national and regional resources to support local efforts - Use measures to promote interaction, deliberation and coordination to manage spill-over effects - Strengthen linkages between formal (e.g., regulatory) and informal (e.g., traditions and rituals) institutions, e.g., through information sharing - Use spatial coordination mechanisms, e.g., land-use planning, to translate national and regional provisions into local competencies community-based and ecosystem-based adaptation to bridge adaptation and mitigation and improve coordination. | Heritage | 3360 - 3361 |
| IPCC | IPCC_AR6_WGII_Full_ Report | - Account for local history, culture and politics through engagement, experimentation and innovation - Generate socio-economic, livelihood and climate�development co-benefits - Leverage national and trans-national community and local authority networks Cape Town, South Africa (4.6mill; mixed): Capable local leaders collaborate with researchers in municipality-initiated community-based adaptation. Translating plans into action challenging given 'everyday' vulnerability exacerbated by climate change impacts. | Heritage | 3361 - 3361 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 10 11 These climate risks at the coast can also be magnified by compounding and cascading effects due to non- 12 climate drivers directly affecting vulnerable peri- and ex-urban areas inland. These risks include disruption 13 to transport supply chains and energy infrastructure from airports and power plants sited along coastal areas, 14 as occurred in New York City, USA, during Hurricane Sandy in 2012. The impacts can be felt around the 15 world through globalized economic and geopolitical linkages, e.g., through maritime trade and port linkages. | Heritage | 3364 - 3364 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 16 17 For open coasts, settlements on low-lying small island states and the Arctic are especially vulnerable to 18 climate change, and sea level rise impacts in particular, well before 2100. While the economic risks may not 19 compare to the scale of those faced in coastal megacities with high per capita GDP, the existential risks to 20 some nations and an array of distinctive livelihoods, cultural heritage, and ways-of-life in these settlements 21 are great, even with modest sea level rise. | Heritage | 3364 - 3364 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 6 7 Coastal risks and impacts such as floods, loss of fisheries or tourism, or salinization of groundwater, require 8 people to change behaviour to adapt, such as diversifying livelihoods or moving away from low-lying areas. | Heritage | 3365 - 3365 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 33 34 Coastal C&S are on the frontline of the climate change challenge. They are the interface of three 35 interconnected realities. First, they are critical nodes of global trade, economic activity and coast-dependent 36 livelihoods, all of which are highly and increasingly exposed to climate- and ocean-driven hazards (FAQ 37 CCP2.1). Second, coastal C&S are also sites where some of the most pressing development challenges are at 38 play (e.g., trade-offs between expanding critical built infrastructure while protecting coastal ecosystems, 39 high economic growth coupled with high inequality in some coastal megacities). Third, coastal C&S are also 40 centres of innovation and creativity, thus presenting a tremendous opportunity for climate action through a 41 range of infrastructural, nature-based, institutional, and behavioural solutions (FAQ CCP2.2). Given these 42 three realities of high climate change risks, rapid but contested and unequal development trajectories, and 43 high potential for innovative climate action, C&S are key to charting pathways for Climate Resilient 44 Development. | Heritage | 3365 - 3365 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 10 11 Where are we now: Observed impacts and adaptation responses 12 13 Deserts and semi-arid areas have already been affected by climate change, with some areas 14 experiencing increases in aridity. Mixed trends of decreases and increases in vegetation productivity 15 have been observed, depending on the time period, geographic region, detection methods used and vegetation type under consideration (high confidence1 16 ). These changes have had varying and location- 17 specific impacts on biodiversity, and have altered ecosystem carbon balance, water availability and the 18 provision of ecosystem services (high confidence). There is no evidence, however, of a global trend in 19 dryland expansion based on analyses of vegetation patterns, precipitation and soil moisture, with 20 overall, more greening than drying in drylands since the 1980s (medium confidence). Deserts and semi- 21 arid areas host unique biodiversity, rich cultural heritage and provide globally valuable ecosystem services. | Heritage | 3383 - 3383 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 22 They are also highly vulnerable to climate change. The vitality of natural ecosystems in arid and semi-arid 23 regions greatly depends on water availability, as they are highly sensitive to changes in precipitation and 24 potential evapotranspiration {3.1.2; 3.2.1}, as well as to land management practices. Multiple lines of 25 evidence from 1920-2015 indicate that surface warming of 1.2ºC-1.3ºC over global drylands (Section 1.1.1) 26 exceeded the 0.8ºC-1.0ºC warming over humid lands. From 1982 to 2015, unsustainable land use and 27 climate change combined caused desertification of 6% of the global dryland area, while 41% showed 28 significant increases in vegetation productivity (greening) and 53% of the area had no notable change, 29 although greening rates are slowing or declining in some locations. Greening may cause biodiversity loss and 30 ecosystem service degradation in relation to livelihood systems {3.2.2}. Observed trends in deserts and semi- 31 arid areas have led to varying impacts on flora, fauna, soil, nutrient cycling, the carbon cycle and water 32 resources. Ecological changes in dryland ecosystems detected and attributed primarily to climate change 33 include tree mortality and losses of mesic tree species at specific sites in the African Sahel particularly 34 during the droughts of the 1970s and 80s, and in North Africa from 1970 to 2007 (CCP4.3.2); and losses of 35 bird species in the Mojave Desert of North America from 1908 to 2016 (CCP4.3.2). In contrast, growth in 36 herbaceous vegetation production has increased in some drylands since the 1980s. Widespread woody 37 encroachment has occurred in many shrublands and savannas in Africa, Australia, North America and South 38 America, due to a combination of land use change, changes in rainfall, fire suppression, and CO2 fertilization 39 {3.2.1, 3.2.2} which, together with unsustainable management, alters biodiversity and reduces ecosystem 40 services such as water availability and grazing potential. | Heritage | 3383 - 3383 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 40 Deserts and semi-arid areas have a rich cultural heritage, Indigenous knowledge, and local knowledge which 41 enrich and influence sustainability and land use globally. Growing research evidence and experience 42 highlight the necessary features of an enabling environment for dryland adaptation (Section 8.5.2). Key 43 enablers include supportive policies, institutions and governance approaches that strengthen the adaptive 44 capacities of dryland farmers, pastoralists and other dryland resource users (high confidence), addressing 45 drivers (proximate and underlying) as well as symptoms of desertification. For instance, the skills and 46 capacities held by the mobile and adaptive approach of pastoralists may provide lessons for society at large 47 in adapting to climate change and dealing with increased uncertainty. Such a policy would stand in contrast 48 to previous attempts at settling pastoralists. There is a persistent gap in terms of scaling-up already known 49 good practices, combining nature-based, land-based, and ecosystem-based approaches that facilitate 50 sustainable land management, with contextually appropriate and responsible governance systems (e.g., 51 including those supporting communal land tenure arrangements and Indigenous knowledge) (medium 2 In this Report, the following terms have been used to indicate the assessed likelihood of an outcome or a result: Virtually certain 99–100% probability, Very likely 90–100%, Likely 66–100%, About as likely as not 33–66%, Unlikely 0–33%, Very unlikely 0–10%, and Exceptionally unlikely 0–1%. Additional terms (Extremely likely: 95– 100%, More likely than not >50–100%, and Extremely unlikely 0–5%) may also be used when appropriate. Assessed likelihood is typeset in italics, e.g., very likely). This Report also uses the term 'likely range' to indicate that the assessed likelihood of an outcome lies within the 17-83% probability range<br>ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Cross-Chapter Paper 3 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP3-4 Total pages: 53 1 confidence). Land based adaptations can help manage dryland changes including sand and dust storms and 2 desertification (high confidence), while technological options linked to water management draw from both 3 traditional practices and new innovations. Adequate financing and investment is required to harness multiple 4 benefits for managing the impacts of climate change and desertification whilst accelerating progress towards 5 sustainable development in deserts and semi-arid areas {3.4}. | Heritage | 3384 - 3385 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 6 7 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Cross-Chapter Paper 3 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP3-5 Total pages: 53 1 CCP3.1 Introduction 2 3 CCP3.1.1 Concepts, Definitions and Scope 4 5 Deserts and semi-arid areas are in 'drylands', which comprise hyper-arid, arid, semi-arid and dry sub-humid 6 areas (Figure CCP3.1). Drylands cover about 45-47% of the global land area (Prăvălie, 2016; Koutroulis, 7 2019) and are home to about 3 billion people residing primarily in semi-arid and dry sub-humid areas (van 8 der Esch et al., 2017). Drylands host unique, rich biodiversity (Maestre et al., 2015) and provide important 9 ecosystem services (Bidak et al., 2015; Lu et al., 2018), while dryland people have a rich cultural and 10 historical heritage. Rural human populations are growing in some Mediterranean and tropical drylands, while 11 many are rapidly urbanizing (Guengant Jean-Pierre, 2003; Tabutin and Schoumaker, 2004; Denis and 12 Moriconi-Ebrard, 2009), with varying impacts on ecosystem services and adaptive capacities. In recent 13 decades, 6% of global megacities have been established in arid areas and 2% in hyper-arid desert areas 14 (Cherlet et al., 2018), with many of these areas suffering from severe water security challenges (Stringer et 15 al., 2021). Dryland inhabitants in many developing countries are also experiencing poverty (Section 16 16.1.4.3), hunger, poor health, land degradation, and economic and political marginalisation (Mbow et al., 17 2019; Mirzabaev et al., 2019), which sometimes limits their access to common pool resources. These 18 challenges, together with a weak enabling environment, threaten opportunities to adapt to climate change. | Heritage | 3385 - 3386 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 47 48 Drylands yield important opportunities for adapting to and mitigating climate change. They offer abundant 49 solar energy which could support mitigation efforts, opportunities for cultural and nature-based tourism, rich 50 plant biodiversity in some areas (e.g. Namibia), and extensive Indigenous knowledge and experience of 51 adapting to dynamic climates (Christie et al., 2014; Stringer et al., 2017), e.g. across West Asia and North 52 Africa (Louhaichi and Tastad, 2010; Hussein, 2011). Improved understanding of challenges and 53 opportunities in drylands can be achieved by transdisciplinary, multi-scale and inter-sectoral approaches 54 encompassing links between physical, biological and socioeconomic, and institutional systems (Reynolds et 55 al., 2007; Stringer et al., 2017). | Heritage | 3386 - 3386 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 4 5 CCP3.2.1.5 Tree Death and Woody Cover Decline 6 7 Field measurements have also detected tree mortality and loss of mesic tree species at some Sahel sites 8 during drought periods (Gonzalez et al., 2012; Kusserow, 2017; Brandt et al., 2018; Ibrahim et al., 2018; 9 Trichon et al., 2018; Zwarts et al., 2018; Bernardino et al., 2020; Zida et al., 2020) and a reduction of mesic 10 species in favour of drought-tolerant species (high confidence) (Hänke et al., 2016; Kusserow, 2017; Ibrahim 11 et al., 2018; Trichon et al., 2018; Dendoncker et al., 2020; Zida et al., 2020b), with attribution to climate 12 change (Gonzalez et al., 2012). Furthermore, vegetation productivity per unit of rainfall showed a net decline 13 of 4% in the period 2000-2015 across drylands globally, with the greatest net declines in Africa (16%) and 14 Asia (33%) (Abel et al., 2021), but with location-specific increases in vegetation-rainfall sensitivity, e.g. in 15 southern and eastern Africa and parts of the Sahel. Furthermore, NDVI declines were reported across the 16 Sahel from 1999 to 2015 (Yuan et al., 2019; Zida et al., 2020a). However, field site monitoring showed a 17 strong regeneration of the decimated woody populations except on shallow soil where the runoff system had 18 evolved towards a web of gullies (Hiernaux et al., 2009a; Trichon et al., 2018; Wendling et al., 2019) . | Heritage | 3390 - 3390 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 19 20 Other site-specific impacts include tree mortality in south-western Morocco (Le Polain de Waroux and 21 Lambin, 2012), mortality of Austrocedrus and Nothofagus forests in the dry Patagonia forest-steppe 22 (Rodríguez-Catón et al., 2019), and a tree range contraction of Aloidendron dichotmum in Southern Africa 23 (Foden et al., 2007b). In Morocco, tree mortality was most highly correlated to an increase in aridity, 24 measured by the Palmer Drought Severity Index (PDSI), which showed a statistically significant increase 25 since 1900 due to climate change (Dai et al., 2004; Esper et al., 2007; Dai, 2011). | Heritage | 3390 - 3390 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 54 55 Qualitative case studies tend to frame conflict and migration within a larger political, economic and 56 historical context. A number of studies from African drylands find that land dispossession is a key driver of 57 both migration and conflict resulting from large-scale resource extraction or land encroachment often ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Cross-Chapter Paper 3 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP3-15 Total pages: 53 1 associated with processes of elite capture and marginalization (Benjaminsen and Ba, 2009; Benjaminsen et 2 al., 2009; Cross, 2013; Glick Schiller, 2015; Nyantakyi-Frimpong and Bezner Kerr, 2017; Obeng-Odoom, 3 2017; Bergius et al., 2020). By undermining livelihoods, exacerbating poverty, and setting rural population 4 groups adrift, land dispossession in the Sahel may lead to increased migration to urban areas, to rural sites of 5 non-farm employment (e.g. mines) (Chevrillon-Guibert et al., 2019) or out of the country. In addition, it may 6 lead to other types of reactions including violent resistance (Oliver-Smith, 2010; Cavanagh and 7 Benjaminsen, 2015; Hall et al., 2015) as already seen in the Sahel in terms of the emergence of jihadist 8 armed groups (Benjaminsen and Ba, 2019). Major drivers of the current crisis in Mali include decades of 9 bureaucratic mismanagement and widespread corruption, the spill-over of jihadist groups from Algeria after 10 the civil war there in the 1990s and the current civil war in Libya. Climate change has played a marginal role 11 as a driver of conflicts in the Sahel (Benjaminsen et al., 2012; Benjaminsen and Hiernaux, 2019) but has 12 potential to exacerbate the situation in the future with regards to migration and conflict (Owain and Maslin, 13 2018). | Heritage | 3395 - 3396 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 31 32 The relative contribution of albedo and evapotranspiration to regional trends in surface temperature 33 (Charney, 1975) remains unresolved, and may be determined by different mechanisms in different systems, 34 depending on site-specific conditions such as snow coverage, vegetation and soil moisture (Yu et al., 2017). | Heritage | 3398 - 3398 |
| IPCC | IPCC_AR6_WGII_Full_ Report | Livestock, human�ignited fires Medium Iknayan and Beissinger (2018); Riddell et al. (2019) Decline of desert tortoise (Gopherus agassizii) population 90% from 1993 to 2012 at one site in the Mojave Decreased rainfall Lovich et al. (2014) Reduced perennial vegetation cover, including trees and cacti, in the Mojave and Sonoran deserts of the southwestern United States Increased temperature, decreased rainfall, wildfire Land use change, invasive plant species High Defalco et al. (2010); Munson et al. (2016b); Conver et al. | Heritage | 3405 - 3405 |
| IPCC | IPCC_AR6_WGII_Full_ Report | (2017) Arid African Sahel Woody cover increase in parts of the Sahel Increase in rainfall since the mid-1990s (compared to 1968-1993)and increased CO2 Restoration planting Agroforestry High ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Cross-Chapter Paper 3 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP3-25 Total pages: 53 Increase in grass production across Sahel Increases in rainfall since the mid-1990s (compared to 1968-1993) and increased CO2 Medium Hiernaux et al. (2009a); Hiernaux et al. (2009b); Dardel et al. (2014); Venter et al. (2018); Zhang et al. (2018); Brandt et al. (2019); Bernardino et al. (2020) Decline of mesic tree species at field sites across the Sahel Decreased rainfall from 1901 to 2002 increased temperature Yes. | Heritage | 3405 - 3406 |
| IPCC | IPCC_AR6_WGII_Full_ Report | Land clearing for cropland expansion, Increase pressure on wood resources (rural demography, urbanization) High Gonzalez (2001); Wezel and Lykke (2006); Maranz (2009); Gonzalez et al. (2012); Hänke et al. (2016); Kusserow (2017); Ibrahim et al. (2018); Zida et al. (2020b) Increased tree mortality at field sites across the Sahel Decreased rainfall from 1901 to 2002, increased temperature Yes. | Heritage | 3406 - 3406 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | Woody encroachment Medium Blaum et al. (2007); Blaum et al. (2009); Sirami and Monadjem (2012); Gray and Bond (2013); Péron and Altwegg (2015); Smit and Prins (2015) African semi�arid regions (savanna) Reduced tourism experience due to woody encroachment Woody encroachment Low Gray and Bond (2013) North American drylands – sagebrush steppes Sagebrush steppes are being invaded by non-native grasses Increase in temperature and favourable climates High Bradley et al. (2016); Hufft and Zelikova (2016); Chambers (2018) Shrub encroachment,(Prosopis glandulosa, Juniper ashei and Juniper pinchotti) is occurring in the semi-arid grasslands of the southern great plains at a rate of ~8% per decade Increasing temperature, elevated CO2 and changing rainfall Fire suppression and altered grazing/browsing regimes High Caracciolo et al. (2016); Archer et al. (2017) Woody encroachment in sagebrush steppes (cold deserts) (Juniper occidentalis) at a rate of 2% per decade a) Warming and associated decline in snowpack b) Less precipitation falling as snow and an increase in the rain fraction in winter. | Heritage | 3411 - 3411 |
| IPCC | IPCC_AR6_WGII_Full_ Report | FINAL DRAFT Cross-Chapter Paper 4 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP4-1 Total pages: 50 1 2 Cross-Chapter Paper 4: Mediterranean Region 3 4 Cross-Chapter Paper Leads: Elham Ali (Egypt), Wolfgang Cramer (France) 5 6 Cross-Chapter Paper Authors: Jofre Carnicer (Spain), Elena Georgopoulou (Greece), Nathalie Hilmi 7 (Monaco), Gonéri Le Cozannet (France), Piero Lionello (Italy) 8 9 Cross-Chapter Paper Contributing Authors: Ahmed Abdelrehim (Egypt), Mine Cinar (USA), Islam 10 Abou El-Magd (Egypt), Shekoofeh Farahmand (Iran), François Gemenne (Belgium), Lena Reimann 11 (Germany), Alain Safa (France), Sergio Vicente-Serrano (Spain), Francesca Spagnuolo (Italy), Duygu Sevgi 12 Sevilgen (Monaco), Samuel Somot (France), Rémi Thiéblemont (France), Cristina Tirado (USA), Yves 13 Tramblay (France) 14 15 Cross-Chapter Paper Review Editors: Karim Hilmi (Morocco), Marta Rivera-Ferre (Spain) 16 17 Cross-Chapter Paper Scientist: Duygu Sevgi Sevilgen (Monaco) 18 19 Date of Draft: 1 October 2021 20 21 Notes: TSU Compiled Version 22 23 24 Table of Contents 25 26 Executive Summary.......................................................................................................................2 27 CCP4.1 Climate Change in the Mediterranean Basin............................................................................4 28 CCP4.1.1 The Mediterranean Sea, Land and People .............................................................................4 29 CCP4.1.2 Main Findings from Previous Assessments ...........................................................................4 30 CCP4.1.3 Observed and Projected Climate Change..............................................................................5 31 CCP4.1.4 Detection and Attribution of Climate Change Impacts..........................................................8 32 CCP4.2 Vulnerability of Mediterranean Countries to Climate Change...............................................9 33 CCP4.2.1 The Specific Vulnerability of Mediterranean countries.........................................................9 34 CCP4.2.2 Economic Vulnerability .........................................................................................................9 35 CCP4.2.3 Social and Human Vulnerability..........................................................................................11 36 CCP4.3 Projected Climate Risks in the Mediterranean Basin ..............................................................12 37 CCP4.3.1 Ocean Systems .....................................................................................................................12 38 CCP4.3.2 Coastal Systems .....................................................................................................................13 39 CCP4.3.3 Inland Ecosystems...................................................................................................................13 40 CCP4.3.4 Water, Agriculture and Food Production............................................................................14 41 CCP4.3.5 Human Health and Cultural Heritage .................................................................................16 42 CCP4.3.6 Synthesis of Key Risks..........................................................................................................16 43 CCP4.4 Adaptation and Sustainable Development in the Mediterranean Basin................................18 44 CCP4.4.1 Ocean and Coastal Systems..................................................................................................18 45 CCP4.4.2 Inland Ecosystems..................................................................................................................18 46 CCP4.4.3 Water Management, Agriculture and Food Security............................................................18 47 CCP4.4.4 Human Health.........................................................................................................................19 48 CCP4.4.5 Limits to Adaptation, Equity and Climate Justice ................................................................19 49 CCP4.4.6 Pathways for Sustainable Development...............................................................................20 50 CCP4.4.7 Governance and Finance for Sustainable Development .........................................................24 51 FAQ CCP4.1: Is the Mediterranean Basin a "climate change hotspot"? ..............................................25 52 FAQ CCP4.2: Can Mediterranean countries adapt to sea-level rise?.......................................................26 53 FAQ CCP4.3: What is the link between climate change and human migration in the Mediterranean 54 Basin?.......................................................................................................................................28 55 References ......................................................................................................................29 56 57 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Cross-Chapter Paper 4 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP4-2 Total pages: 50 1 Executive Summary 2 3 | Heritage | 3434 - 3436 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 29 These impacts include multiple consequences of longer and/or more intensive heat waves, droughts, floods, 30 ocean acidification and sea-level rise, such as cascading impacts on marine and terrestrial ecosystems as well 31 as on land and sea use (agriculture, forestry, fisheries, tourism, recreation etc.) and human health. | Heritage | 3436 - 3436 |

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|---|---|---|---|---|
| IPCC | IPCC_AR6_WGII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Cross-Chapter Paper 4 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP4-3 Total pages: 50 1 Coastal flood risks will increase in low-lying areas along 37% of the Mediterranean coastline that currently 2 host 42 million people. The number of people exposed to sea-level rise is projected to increase up to 2050, 3 especially in the Southern and Eastern Mediterranean region, and may reach up to 130% compared to present 4 in 2100 (medium confidence). Coastal settlements, world heritage sites and ecosystems are at longer-term 5 risk from sustained sea-level rise over at least the coming three centuries (high confidence). {CCP4.1.3, 6 CCP4.2, CCP4.3, SMCCP4.4} 7 8 Due to its particular combination of multiple strong climate hazards and high vulnerability, the 9 Mediterranean region is a hotspot for highly interconnected climate risks. The main economic sectors in 10 the region (agriculture, fisheries, forestry, tourism) are highly vulnerable to climatic hazards, while socio- 11 economic vulnerability is also considerable. The low-lying areas are the most vulnerable areas for coastal 12 climate-related risks (e.g. sea level rise, floods, erosion) and other consequent risks (e.g. saltwater intrusion 13 and agriculture damage) (high confidence). Climate change threatens water availability, reducing river low 14 flows and annual runoff by 5-70%, reducing hydropower capacity (high confidence). Yields of rain-fed crops 15 may decrease by 64% in some locations (high confidence). Ocean warming and acidification will impact 16 marine ecosystems, with uncertain consequences on fisheries (low confidence). Desertification will affect 17 additional areas, notably in the South and South-East (medium confidence). Burnt area of forests may 18 increase by 96-187% under 3°C, depending on fire management (low confidence). Beyond 3°C, 13-30% of 19 the Natura 2000 protected area and 15-23% of Natura 2000 sites could be lost due to climate-driven habitat 20 change (medium confidence). {CCP4.2, CCP4.3} 21 22 The adaptive capacity of ecosystems and human systems is expected to encounter hard limits due to 23 the interacting, cumulative and cascading effects of droughts, heat waves, sea-level rise, ocean 24 warming and acidification (high confidence). Coastal protection can reduce risks from sea-level rise in 25 some regions, but the costs of such interventions and their consequences for coastal ecosystems are high 26 (medium confidence) {CCP4.4.1}. There is low confidence in the feasibility of adaptation options to sea- 27 level rise beyond 2100 or for large Antarctic ice melting. {CCP4.4.5} 28 29 Progress towards achievement of the UN Sustainable Development Goals differs strongly between 30 Mediterranean sub-regions, with north-western countries having stronger resilience than southern 31 and eastern countries (high confidence). To equitably enhance regional adaptive capacity and sustainable 32 development, while safeguarding the rights of the most vulnerable people, regional cooperation can be 33 strengthened with a focus on the link between adaptation, costs and financial limitation and climate justice 34 (high confidence). Cooperative policies across multiple various sectors, involving all user groups and 35 considering all regional and sectorial differences may enhance sustainable resource use in the region (high 36 confidence). {CCP4.4.6} 37 38 Sharing and co-production of knowledge can support climate adaptation practices and enhance 39 sustainability in the Mediterranean region (medium to high confidence). Currently incomplete 40 knowledge of climate impacts and risks in the southern and eastern part of the basin hinders the 41 implementation of adaptation measures, creating a need for implementable plans with enhanced and 42 cooperative research and monitoring capacities between the north and south/east countries (high agreement). | Heritage | 3436 - 3437 |
| IPCC | IPCC_AR6_WGII_Full_Report | 43 {CCP4.4} 44 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Cross-Chapter Paper 4 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP4-4 Total pages: 50 1 CCP4.1 Climate Change in the Mediterranean Basin 2 3 CCP4.1.1 The Mediterranean Sea, Land and People 4 5 The Mediterranean Basin, known for its exceptional environmental and socio-cultural richness, comprises the semi-enclosed Mediterranean Sea and the countries and regions bordering it3 6 , which belong to Europe, 7 Asia and Africa (Figure CCP4.1). The region has a unique historical and environmental identity (Abulafia, 8 2011), despite undeniable variations in the environment, socio-economic conditions and cultural traditions. | Heritage | 3437 - 3438 |
| IPCC | IPCC_AR6_WGII_Full_Report | 34 3 By tradition, also Portugal and Jordan are considered Mediterranean countries, despite having no Mediterranean coastline ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Cross-Chapter Paper 4 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP4-5 Total pages: 50 1 With the changing climate, marine ecosystems have already undergone changes in structure, including the 2 spread of tropical species from the Atlantic Ocean and the Red Sea (high confidence) and mass mortality in 3 at least 25 invertebrate species, threatening, along with ocean acidification, marine ecosystems, including 4 seagrass meadows (Hoegh-Guldberg et al., 2014; Nurse et al., 2014; Pörtner et al., 2014; Wong et al., 2014). | Heritage | 3438 - 3439 |
| IPCC | IPCC_AR6_WGII_Full_Report | 19 20 The increasing water scarcity was found to be a significant threat to agriculture (Jiménez Cisneros et al., 21 2014; Kovats et al., 2014; Niang et al., 2014; Mrabet et al., 2020). Associated with increased extreme 22 temperatures, the Mediterranean is expected to become less attractive for tourism (Kovats et al., 2014; Nurse 23 et al., 2014; Wong et al., 2014; Dos Santos et al., 2020). Several critical risks for human health increase due 24 to climate change, including heat waves and vector-borne diseases (Kovats et al., 2014; Nurse et al., 2014; 25 Linares et al., 2020). Adaptation options have been identified for many risks (buildings, water management, 26 coastal protection etc.) (Murray et al., 2012; Revi et al., 2014; Wong et al., 2014). There are synergies 27 between adaptation and mitigation, e.g. renewable energies or nature-based solutions focused on the 28 conservation and restoration of ecosystems (Nurse et al., 2014; Hoegh-Guldberg et al., 2018; Vafeidis et al., 29 2020). | Heritage | 3439 - 3439 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 30 31 32 CCP4.2 Vulnerability of Mediterranean Countries to Climate Change 33 34 CCP4.2.1 The Specific Vulnerability of Mediterranean countries 35 36 The Mediterranean region is predominantly vulnerable to the impacts of warming, notably prolonged and 37 stronger heat waves, and increased drought in an already dry climate, and risk of coastal flooding (Section 38 CCP4.1). Southern and Eastern countries are generally more vulnerable than countries in the north. Several 39 countries (Tunisia, Algeria and Libya) are below the water scarcity threshold set by the Food and Agriculture 40 Organization of the United Nations (FAO), others (Morocco) are close to the threshold for severe water 41 stress. Uncertainties regarding the timing, duration, intensity and interval between extreme climatic events 42 put some sectors such as agriculture and tourism at particular risk in the Mediterranean region (Section 43 CCP4.3; Kallis, 2008; Kutiel, 2019). | Heritage | 3443 - 3443 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 56 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Cross-Chapter Paper 4 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP4-11 Total pages: 50 1 The Mediterranean region accounts for one third of global tourism with 330 million tourists in 2016 (Tovar- 2 Sánchez et al., 2019). Before the COVID-19 crisis, international tourist arrivals were assumed to increase by 3 60% between 2015 and 2030 and reach 500 million then. In 2015, tourism supported 15% of the total 4 employment in the region (Randone et al., 2017). France, Spain, Italy and Greece are the top tourist 5 destinations (UNWTO, 2016), but the highest growth was in Turkey, Croatia and Albania during 1995-2015 6 (MGI, 2017). The tourism industry is vulnerable to climate change, particularly in low income countries 7 (Dogru et al., 2016; Dogru et al., 2019). Coastal tourism in the region generates 300 billion USD annually 8 followed by marine tourism (110 billion USD) (Radhouane, 2013; Randone et al., 2017). | Heritage | 3444 - 3445 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 47 48 Combined with storm surges, sea-level rise may disrupt Mediterranean port operations (Sánchez-Arcilla et 49 al., 2016; Sierra et al., 2016), with risks depending on adaptation, physical protection measures and basin 50 depth. Risks for deep ports are more limited (Sierra et al., 2017), while low-depth small harbours, common 51 in the Mediterranean, could be significantly affected (Sierra et al., 2016). Sea-level rise may enhance sandy 52 beach erosion and thereby impact recreation and tourism (Bitan and Zviely, 2018; Rizzetto, 2020), 53 magnifying coastal degradation and pollution (Enríquez et al., 2017; Gössling et al., 2018). | Heritage | 3447 - 3447 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 54 55 CCP4.3.3 Inland Ecosystems 56 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Cross-Chapter Paper 4 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP4-14 Total pages: 50 1 Beyond 3°C GWL, 13-30% of the Mediterranean Natura 2000 protected area and 15 to 23% of Natura 2000 2 sites are projected to change towards more arid ecosystem types (Barredo et al., 2016). Biodiversity and 3 ecosystem services would be exposed to degradation of wetland hydrology, which could affect 19-32% of 4 localities under a 1.5 to 2°C GWL (48-73% under higher warming), particularly in Spain, Portugal, Morocco 5 and Algeria (Lefebvre et al., 2019) and a substantial shrinking of terrestrial and freshwater ecosystem 6 habitats, in particular in Mediterranean islands (Chapters 2 and 4; CCP1). | Heritage | 3447 - 3448 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 9 Increasing heat waves, combined with drought and land-use change, reduce fuel moisture, thereby increasing 10 fire risk, extending the duration of fire seasons and increasing the likelihood of large, severe fires (high 11 confidence) (EEA, 2017; Lozano et al., 2017; Peñuelas et al., 2017; Varela et al., 2019). Fires impact 12 vegetation recovery after abandonment, thus transforming landscapes (González-De Vega et al., 2016). At 13 warming levels of 1.5°C, 2°C and 3°C, burnt area in Mediterranean Europe could increase by 40-54%, 62- 14 87% and 96-187%, respectively (Turco et al., 2018b), although changes are highly site-dependant and also 15 affected by management (Caon et al., 2014; Wu et al., 2015; Parra and Moreno, 2018; Brotons and Duane, 16 2019; Hinojosa et al., 2019). | Heritage | 3448 - 3448 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 9 10 CCP4.3.5 Human Health and Cultural Heritage 11 12 Warming is projected to impact human health, mostly through increased intensity, frequency and duration of 13 heat waves (high confidence) (Guerreiro et al., 2018; Jacob et al., 2018; Rohat et al., 2019; Smid et al., 14 2019). Under current socio-economic conditions, 53-93 million more people could be exposed to high or 15 very high heat stress in northern Mediterranean by 2050 (Gasparrini et al., 2017; Rohat et al., 2019) and 16 heat-related excess mortality could increase by more than 6-fold above 3°C GWL (Gasparrini et al., 2017; 17 Rohat et al., 2019). In MENA countries, the mortality risk of the elderly in 2100 could be 8-20 times higher 18 under RCP8.5 compared to 1951-2005, and still 3-7 times higher under RCP4.5 (Ahmadalipour and 19 Moradkhani, 2018). Deaths attributable to high temperatures in the northern Mediterranean could increase by 20 18-20,000 in 2050 (50,000 in 2100) under RCP8.5 (1.4 and 2.6 times lower under RCP4.5) (Kendrovski et 21 al., 2017). | Heritage | 3450 - 3450 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 39 40 Many studies project a decrease of climatic comfort for tourism in the Mediterranean by 2071 to 2100, 41 particularly during summer (Grillakis et al., 2016; Jacob et al., 2018; Braki and Anagnostopoulou, 2019). | Heritage | 3450 - 3450 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 42 There is adaptive potential in the extension of the period with favourable climatic conditions for urban 43 tourism in Mediterranean cities (Scott et al., 2016). Water scarcity may create additional constraints for 44 tourism (Köberl et al., 2016). | Heritage | 3450 - 3450 |

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| IPCC | IPCC_AR6_WGII_Full_Report | 45 46 Cultural heritage sites in the region face risks from coastal flooding, with 37 out of 49 cultural World 47 Heritage Sites today facing risk from a 100-year flood, and 42 of them from coastal erosion (Reimann et al., 48 2018b). Sea-level rise will increase these risks (high confidence) (Lionello, 2012; Rizzi et al., 2017; Reimann 49 et al., 2018b; Ravanelli et al., 2019; Tagliapietra et al., 2019). By 2100, 47 of the 49 UNESCO sites are 50 projected to be at risk from coastal flooding or erosion (Reimann et al., 2018b). Beyond 2100, sea levels are 51 committed to rise further and represent an existential threat for the high number of coastal cultural heritage 52 located in the Mediterranean (AR6 WGI Chapter 9; Chapter 13; Cross-Chapter Box SLR in Chapter 3; 53 Marzeion and Levermann, 2014). | Heritage | 3450 - 3450 |
| IPCC | IPCC_AR6_WGII_Full_Report | 6 7 8 9 Figure CCP4.7: Key risks in the Mediterranean and their location for SSP5-RCP8.5 by 2100 across the Mediterranean 10 region for SSP5-RCP8.5 by 2100 (Sections CCP4.3.2-6 and Table SMCCP4.2a & b for details). Risks to world cultural 11 heritage sites from flooding or erosion due to sea-level rise in multiple locations (section CCP4.3.5) and Mediterranean 12 river deltas are hotspots of vulnerability to climate change (Section CCP4.3.2). The population exposed to risks is 13 mapped for an SSP5-8.5 pathway. Adaptation can reduce these risks (Section CCP4.4) (based on: Reimann et al., 14 2018a; Reimann et al., 2018b; Wolff et al., 2018). | Heritage | 3451 - 3451 |
| IPCC | IPCC_AR6_WGII_Full_Report | 15 16 17 18 Figure CCP4.8: Summary of key risks for the Mediterranean (Sections CCP4.3.2-8 and Supplementary Tables 19 SMCCP4.2a-h for details). Coastal risks include one burning ember displaying additional risks due to climate change as 20 specific GWL are exceeded (Coastal risks), and one burning ember describing additional risks due to committed sea- 21 level rise at timescales of centuries and millennia for long living infrastructure and cultural heritage (AR6 WGI Chapter 22 9; Marzeion et al., 2014; Marzeion and Levermann, 2014; Clark et al., 2016; see SMCCP4.2h). | Heritage | 3451 - 3451 |
| IPCC | IPCC_AR6_WGII_Full_Report | 4 5 Technical options include the reduction of losses in water distribution networks for drinking water and 6 irrigation (Burak and Margat, 2016; Fader et al., 2016), desalinization, often combined with generation of 7 electricity (Papanicolas et al., 2016; Bonanos et al., 2017; Jones et al., 2019), artificial recharge of 8 groundwater and subterranean dams (Djuma et al., 2017; De Giglio et al., 2018; Missimer and Maliva, 2018; 9 Baena-Ruiz et al., 2020), and waste water reuse (Kalavrouziotis et al., 2015; Barba-Suñol et al., 2018; 10 Cherfouh et al., 2018). On the demand side, options include changing diet and water consumption patterns 11 (Blas et al., 2016; Gul et al., 2017; Blas et al., 2018) and enhancing water use efficiency in the tourism and 12 food sector (Hadjikakou et al., 2013; Moresi, 2014). | Heritage | 3453 - 3453 |
| IPCC | IPCC_AR6_WGII_Full_Report | 42 43 44 Table CCP4.2: Transformative adaptation and mitigation options for climate resilient sustainable development in the 45 Mediterranean Basin Code Sector Transformative option References T1 Energy, transport and tourism National plans and regulations to decarbonise fuel sources and electricity grids on the supply side, for reducing energy demand and increasing efficiency and converting transport systems from fossil fuels to electricity UNEP/MAP (2016); Bastianin et al. (2017); EEA (2018a); EEA (2018b); OME (2018); CMI and EC (2019); EEA (2019); Sachs et al. (2019); EC, (2020); Simionescu et al. (2020) T2 Energy Deployment of large-scale Mediterranean transboundary renewable energy infrastructures and interconnections. Transboundary energy market integration schemes. | Heritage | 3454 - 3454 |
| IPCC | IPCC_AR6_WGII_Full_Report | 35 36 In general, increasing temperatures and more intensive heatwaves in the basin threaten human well-being, 37 economic activities and also many ecosystems on land and in the ocean. Extreme rainfall events, which 38 despite the lower total rainfall are expected to increase in intensity and frequency in some regions, generate 39 significant risks for infrastructure and people through flash floods. Warming also affects the ocean and its 40 ecosystems, jointly with acidification caused by atmospheric carbon dioxide. Finally, sea-level rise, currently 41 accelerating as a consequence of global ice loss, threatens coastal ecosystems, historical sites and a growing 42 human population. | Heritage | 3459 - 3459 |
| IPCC | IPCC_AR6_WGII_Full_Report | 5 6 7 Risks associated with projected climate change are particularly high for people and ecosystems in the 8 Mediterranean Basin due to the unique combination of many factors, including: 9 i) a large and growing urban population exposed to heat waves, with limited access to air conditioning, 10 ii) a large and growing number of people living in settlements impacted by rising sea level, 11 iii) important and increasing water shortages, experienced by 180 million people today already, 12 iv) growing demand for water by agriculture for on irrigation, 13 v) high economic dependency on tourism, which is likely to suffer from increasing heat but also from the 14 consequences of international emission reduction policies on aviation and cruise-ship travel, 15 vi) loss of ecosystems in the ocean, wetlands, rivers and also uplands, many of which are already 16 endangered by unsustainable practices (e.g. overfishing, land use change). | Heritage | 3460 - 3460 |
| IPCC | IPCC_AR6_WGII_Full_Report | 30 Sea level in the Mediterranean has been rising by only 1.4 mm yr-1 31 during the 20th century, more recently by 2.4±0.5mm yr−1 32 from 1993 to 2012, and it is bound to continue rising in the future. Future rates are projected 33 to be similar to the global mean (within an uncertainty of 10-20 cm), potentially reaching 1.1 m or more 34 around 2100 in the event of 3°C of global warming (Figure FAQ-CCP4.2; SMCCP4.4). Due to the ongoing 35 ice loss in Greenland and Antarctica, this trend is expected to continue in coming centuries. Sea-level rise 36 already impacts extreme coastal waters around the Mediterranean and it is projected to increase coastal 37 flooding, erosion and salinization risks. These impacts would affect agriculture, fisheries and aquaculture, 38 urban development, port operations, tourism, cultural sites, and many coastal ecosystems. | Heritage | 3460 - 3460 |

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| IPCC | IPCC_AR6_WGII_Full_Report | 39 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Cross-Chapter Paper 4 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP4-27 Total pages: 50 1 Most of the Mediterranean Sea is a micro-tidal environment, which means that the difference between 2 regular high and mean water levels (astronomical tides) is very small. Storm surges and waves can produce 3 coastal floods that persist for several hours, causing particularly large impacts on sandy coasts and eventually 4 also on coastal infrastructure. Mediterranean coasts are also characterized by narrow sandy beaches that are 5 highly valuable for coastal ecosystems and tourism. These beaches are projected to be increasingly affected 6 by erosion and eventually disappear where sedimentary stocks are small. | Heritage | 3460 - 3461 |
| IPCC | IPCC_AR6_WGII_Full_Report | 7 8 Overall, Mediterranean low-lying areas of significant width occur along 37% of the coastline and currently 9 host 42 million inhabitants. The coastal population growth projected until 2050 mostly occurs in southern 10 Mediterranean countries, with Egypt, Libya, Morocco and Tunisia being the most exposed countries to 11 future sea-level rise. The area at risk also hosts 49 cultural World Heritage Sites, including the city of Venice 12 and the early Christian monuments of Ravenna. The Mediterranean also includes areas subjected to sinking 13 of the land (subsidence), including the eastern Nile delta (Egypt) and the Thessaloniki flood plain (Greece), where local relative sea-level rise can exceed 1 cm yr-1 14 today. | Heritage | 3461 - 3461 |
| IPCC | IPCC_AR6_WGII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Cross-Chapter Paper 5 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP5-4 Total pages: 63 1 land-use change and management also play a role (medium confidence). {CCP5.2.3; CCP5.2.5; Table 2 CCP5.2; SROCC Section 2.3.1.3.2; SROCC Section 2.3.7} 3 4 While contributing to poverty reduction in some mountain regions, there is limited evidence of 5 adaptations effectively contributing to remediating the underlying social determinants of vulnerability 6 such as gender and ethnicity (medium confidence). Exposure and vulnerability exacerbate the negative 7 effects of climate impacts on livelihoods, and intertwines with power imbalances, gender and other 8 inequalities (medium confidence). {CCP5.2.7; CCP5.3.2.2} 9 10 Observed changes in seasonality (timing and extent) are negatively affecting mountain winter tourism 11 and recreation (high confidence), and variably affect tourism and recreation activities in other seasons 12 (medium confidence). For winter activities such as skiing, diminishing snow at lower elevations has 13 challenged their operating conditions (medium confidence), increasing the demand for and dependence on 14 snow management measures such as snow-making (high confidence). Climate-induced hazards are 15 negatively affecting some climbing, mountaineering, and hiking routes (medium confidence). In some 16 regions, options to change routes or shift seasons to reduce hazard exposure have been employed as 17 adaptation strategies, with variable outcomes (medium confidence). In some cases, higher temperatures and 18 extreme heatwave conditions at lower elevations have made some mountain destinations more appealing, 19 increasing the potential for summer visitation demand (medium confidence). {CCP5.2.5; Table CCP5.2; 20 SROCC Ch2.3.5} 21 22 Climate-related hazards, such as flash floods and landslides, have contributed to an increase in 23 disasters affecting a growing number of people in mountain regions and further downstream (high 24 confidence). The resulting number of disasters has increased, however there is limited evidence that this is 25 due to changes in the underlying hazard processes, pointing mainly to increasing levels of exposure (medium 26 confidence). {CCP5.2.6; CCP5.2.7; CCP5.3.2.1}. | Heritage | 3487 - 3488 |
| IPCC | IPCC_AR6_WGII_Full_Report | 27 28 Adaptation responses to climate-driven impacts in mountain regions vary significantly in terms of 29 goals and priorities, scope, depth and speed of implementation, governance and modes of decision- 30 making, and the extent of financial and other resources to implement them (high confidence). Observed 31 adaptation responses in mountains are largely incremental and mainly focus on early warning systems and 32 the diversification of livelihood strategies in smallholder agriculture, pastoralism, and tourism. However, 33 there is limited evidence of the feasibility and long-term effectiveness of these measures to address climate- 34 related impacts and related losses and damages, including in cities and settlements experiencing changing 35 demographics. {CCP5.2.4; CCP5.2.7.2} 36 37 Projected impacts, key risks and limits to adaptation in mountains 38 39 Increasing temperatures will continue to induce changes in mountain regions throughout the 21st 40 century, with expected negative consequences for mountain cryosphere, biodiversity, ecosystem 41 services and human wellbeing (very high confidence). Many low elevation and small glaciers around the world will lose most of their total mass at 1.5° 42 C GWL (high confidence). A large majority of endemic 43 mountain species will be at risk of extinction; regions heavily relying on glacier- and snow-melt for 44 irrigation will face erratic water supply and increased food insecurity, whereas agriculture in some regions 45 might see positive changes. Damages and losses from water related hazards such as floods and landslides are 46 projected to increase considerably between 1.5 and 3° GWL. {CCP5.3.1} 47 48 Projected changes in hazards, such as floods and landslides, as well as changes in the water cycle, will 49 lead to severe risk consequences for people, infrastructure and the economy in many mountain regions 50 (high confidence). These risks will be more pervasive and also increase more rapidly in South and Central 51 Asia and Northwestern South America. However, nearly all mountain regions will face at least moderate and 52 some regions even high risks at around 2°C GWL (medium confidence). {CCP5.3.2.1, CCP5.3.2.2; 16.B.4} 53 54 There is an increasing risk of local and global species extinctions where they are not able to move to 55 higher elevations or other cooler locations (high confidence), with risks from extreme events such as 56 wildfire potentially exacerbating those risks (medium confidence). The topographic variation in 57 mountains may mean that some species can survive in cooler microclimates with aspect as well as elevation. | Heritage | 3488 - 3488 |

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| IPCC | IPCC_AR6_WGII_Full_Report | 10 However, there is limited evidence on the magnitude of the consequences. {CCP5.3.2.4; 16.5.2.1; 16.5.2.3.7} 11 12 Options for future adaptation and climate resilient sustainable development in mountains 13 14 The current pace, depth and scope of adaptation is insufficient to address future risks in mountain 15 regions, particularly at higher warming levels (high confidence). While the incremental nature of most 16 implemented adaptations will not be sufficient to reduce severe risk consequences, options exist which offer 17 practical and timely prospects to address risks before limits to adaptation are reached or exceeded. Reducing 18 climate risks will depend on addressing the root causes of vulnerability, which include poverty, 19 marginalization, and inequitable gender dynamics (high confidence). {CCP5.4.1, Figure CCP5.7: CCP5.4.2, 20 Cross-Chapter Box DEEP in Chapter 17; Cross-Chapter Box LOSS in Chapter 17; 17.3, 17.6} 21 22 Adaptation decision-making processes that engage with and incorporate people's concerns and values 23 and address multiple risks are more robust than those with a narrow focus on single risks (medium 24 confidence). Risk management strategies that better integrate the adaptation needs of all affected sectors, 25 account for different risk perceptions and build on multiple and diverse knowledge systems, including 26 Indigenous knowledge and local knowledge, are important enabling conditions to reduce risk severity 27 (medium confidence). {CCP5.2.6, CCP5.4.2; 17.3; 17.4; Cross-Chapter Box PROGRESS in Chapter 17; 28 Cross-Chapter Box DEEP in Chapter 17} 29 30 Regional cooperation and transboundary governance in mountain regions, supported by multi-scale 31 knowledge networks and monitoring programmes, enable long-term adaptation actions where risks 32 transcend boundaries and jurisdictions (medium confidence). Collectively, they show potential to form 33 an important component of the adaptation solution space in mountains. There are increasing calls for more 34 ambitious climate action in mountains, providing impetus for stronger cooperation within and across 35 mountain regions, and downstream areas (medium confidence). {CCP5.4.2; CCP5.4.3} 36 With warming above 1.5o 37 C, the need for adaptation to address key risks in mountains becomes 38 increasingly urgent (high confidence). Pathways and system transitions that strengthen climate-resilient 39 sustainable mountain development are starting to receive attention, but current levels of resourcing are 40 substantially insufficient to support timely action. {CCP5.4.2; CCP5.4.3; CCP5.5; 18.1; 18.2} 41 42 43 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Cross-Chapter Paper 5 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP5-6 Total pages: 63 1 CCP5.1 Point of Departure 2 3 Mountains are an extensive and significant typological region (Section 1.3.3 and AR6 Glossary) in the 4 context of climate change and sustainable development, with a large population directly or indirectly 5 depending on mountains. These are areas of high biological and cultural diversity that provide vital goods 6 and services – such as water, food, energy, minerals, medicinal plants, tourism and recreation, and aesthetic 7 and spiritual values – to people living in and around these mountain regions and in downstream areas. | Heritage | 3489 - 3490 |
| IPCC | IPCC_AR6_WGII_Full_Report | 8 Mountain regions are hotspots of climate related losses in, for example, ecosystems, landscapes, culture, and 9 habitability, and while mountain people are adaptive, resourceful, and independent, they live in highly fragile 10 environments and in some regions under challenging socioeconomic circumstances that enhance their 11 vulnerability to climate change (Alfthan et al., 2018). | Heritage | 3490 - 3490 |
| IPCC | IPCC_AR6_WGII_Full_Report | 30 31 Changes in mountain biodiversity and ecosystems have a wide range of impacts on ecosystem services and 32 effects on people. Some mountain ecosystems, particularly those with peatlands or forests are important 33 carbon stores and climate change presents a risk to these in some locations (Dwire et al., 2018) (Sections 34 2.4.3.8; 2.4.4.4; 2.4.4.5). Palomo (2017) identified a wide range of threats to the lives, livelihoods and 35 culture of mountain people as a consequence of the impacts of climate change on ecosystems. However, 36 impacts are very heterogeneous between locations, even within the same region and ecosystem type (for 37 example mountain forests in Europe; Mina et al. (2017) and are not necessarily all negative. As well as 38 changes in services, other impacts on humans from a changing climate may be mediated through species and 39 ecosystems, for example changes in vector distribution shifting disease incidence into higher elevation areas 40 (Escobar et al., 2016). | Heritage | 3493 - 3493 |
| IPCC | IPCC_AR6_WGII_Full_Report | 18 19 Water plays a fundamental role in climate change adaptation in mountains. A majority of documented 20 adaptation efforts in mountain regions address water-related aspects (precipitation variability and extremes, 21 including drought, water availability, floods) (McDowell et al., 2019; McDowell et al., 2020) (high 22 confidence). This is a robust finding across different mountain regions and adaptation project and program 23 types, and also in line with findings for cryosphere change related adaptation as reported in SROCC (Hock et 24 al., 2019). Water also plays a role for adaptation in other sectors such as agriculture, disaster management 25 and tourism and recreation (McDowell et al., 2019). There is high confidence that water conservation efforts, 26 also including restoration and protection of particularly vulnerable areas (e.g., wetlands), and increase of 27 efficiency in water use, are robust, low-regret adaptation measures. | Heritage | 3496 - 3496 |
| IPCC | IPCC_AR6_WGII_Full_Report | 48 49 Ecosystem products are vital to support the livelihoods and economic prospects for communities living in 50 and around mountains (Figure CCP5.3). For instance, collection and trade of caterpillar fungus contributed 51 to 53.3 - 64.5% annual household cash income in Nepal (Shrestha and Bawa, 2014; Shrestha et al., 2019); 52 40-80% in Bhutan (Thapa et al., 2018); 60-78% in Uttarakhand, India (Laha et al., 2018; Yadav et al., 2019) 53 (Section 5.7.1). Livelihood support from ecosystem products in Southern Malawi region (Pullanikkatil et al., 54 2020), south-western Ethiopian mountains (Nischalke et al., 2017) and Southern China (Min et al., 2017), 55 Himalayan mountains (Nepal et al., 2018), South Africa (Ngwenya et al., 2019) is reported. Additionally, the 56 sacredness of mountains in different religions and cultures is widely acknowledged (Ceruti, 2019; Benedetti 57 et al., 2021). | Heritage | 3498 - 3498 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 25 26 CCP5.2.5 Mountain Communities, Livelihoods, Health and Wellbeing 27 28 People living in and around mountain regions strongly depend on the ecosystem functions, services and 29 resources available in these areas for their livelihoods, health and wellbeing. Overall, subsistence agriculture 30 and livestock remain key sources of livelihood in many mountain regions (FAO, 2019), with non-agricultural 31 income sources such as remittances, small businesses, medicinal plants, wage labour and tourism also 32 contributing to these economies (Montanari and Koutsoyiannis, 2014; Palomo, 2017; Minta et al., 2018). | Heritage | 3501 - 3501 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 33 This section provides an illustrative overview of key reported observed impacts and adaptation responses to 34 climate change on mountain communities (Table CCP5.1), and livelihood activities and economic sectors 35 such as agriculture and pastoralism, and tourism and recreation (Table CCP5.2), reported since AR5. | Heritage | 3501 - 3501 |
| IPCC | IPCC_AR6_WGII_Full_ Report | Furu and Van (2013); Section CCP5.4.1 1 2 3 Table CCP5.2: Overview of key observed impacts and adaptation on select livelihood activities and economic sectors 4 – mountain agriculture and pastoralism; and tourism and recreation. | Heritage | 3503 - 3503 |
| IPCC | IPCC_AR6_WGII_Full_ Report | Reid (2016); Grêt-Regamey and Weibel (2020); Cross-Chapter Box NATURAL in Chapter 2 Tourism and Recreation Impacts • Since SROCC, the literature on climate change impacts on ski winter tourism has remained dominated by studies focused on future climate change impacts and projected risks due to decreasing seasonal snow reliability (see CCP5.3.1), most relevant when considering snow management and in particular snowmaking. | Heritage | 3504 - 3504 |
| IPCC | IPCC_AR6_WGII_Full_ Report | Hock et al. (2019); Mourey et al. (2019); Mourey et al. (2020) • Higher temperatures and extreme heatwave conditions at lower elevations have made some mountain destinations more appealing for human comfort, increasing the potential summer visitation demand and opportunities for tourism and recreation in mountains, such as in the European Alps and the Catalan Pyrenees (medium confidence). However, there is limited evidence reported for similar trends in mountain regions outside of Europe. | Heritage | 3504 - 3504 |
| IPCC | IPCC_AR6_WGII_Full_ Report | (2019a); Juschten et al. (2019b) Responses and adaptation • Diversification of tourism activities to non-snow activities is reported as an adaptation approach to maintain economic viability in some winter ski areas, partly due to the high cost of running snowmaking infrastructure in winter e.g. in the Pyrenees (Europe) and Australian Alps. | Heritage | 3504 - 3504 |
| IPCC | IPCC_AR6_WGII_Full_ Report | Hock et al. (2019); Mourey et al. (2019); Mourey et al. (2020) ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Cross-Chapter Paper 5 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP5-21 Total pages: 63 Overview of key observed impacts and adaptation on select livelihood activities and economic sectors References and relevant AR6 WGII Sections • In some cases, such as in Bolivia, Peru, and New Zealand, and more recently reported in the French Alps, 'last chance' tourism has increased the appeal of some mountain destinations, resulting in visitation demand to witness the effects of climate change on iconic mountain landscape features such as glaciers. | Heritage | 3504 - 3505 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 28 29 Climate change impacts have been documented in mountains of all continents. A wide range of human and 30 natural systems have been affected by climate change to date, including the cryosphere, water resources, 31 terrestrial and aquatic ecosystems, agriculture, tourism, energy production, infrastructure, health and life, 32 migration, disasters and community and cultural values. The confidence levels for detection of impacts are 33 generally in the range of medium to high. The contribution of climate change to the detected impact varies 34 depending on the affected system, and climatic and non-climatic drivers. The highest levels of confidence for 35 attribution of detected impacts to anthropogenic climate change is assigned to the cryosphere. More 36 generally, those impacts are more strongly driven by increasing temperatures and show higher confidence for 37 attribution than those impacts mainly driven by precipitation changes. The level of contribution of climate 38 change to observed impacts is predominantly medium or high, indicating the high sensitivity of natural and 39 human systems in mountains to climate change. Furthermore, the vast majority of detected impacts imply 40 negative impacts on natural and human systems (high confidence). | Heritage | 3506 - 3506 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 47 48 Furthermore, the science of attributing negative impacts of climate change to anthropogenic emissions or 49 even individual polluters is becoming increasingly important for climate litigation (Marjanac et al., 2017; 50 McCormick et al., 2017; Otto et al., 2017; Setzer and Vanhala, 2019) and there is emerging evidence that 51 mountains are becoming sites of litigation cases, with cases for instance in Peru, Colombia, and India 52 (UNEP, 2017). Recent studies put litigation cases such as the Lliuya vs RWE case on risk of glacier lake 53 floods in Peru in a broader context of differentiated responsibilities and justice (Huggel et al., 2020b). | Heritage | 3506 - 3506 |

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| IPCC | IPCC_AR6_WGII_Full_Report | 20 21 Since SROCC (Hock et al., 2019), several new studies have addressed projected impacts of future climate 22 change on snow reliability in ski resorts, complementing previous findings or bridging existing knowledge 23 gaps for winter tourism. This includes, in particular, new studies for China (An et al., 2019; Fang et al., 24 2019), showing that average ski seasons are projected to shorten (-4 to -61% for RCP4.5; -6 to -79% RCP8.5 25 in the 2050s) along with increases in snowmaking water demand (27 to 51% for RCP4.5; 46 to 80% for 26 RCP8.5 in the 2050s), with large differences across the country. Changes in future snow reliability are 27 projected across Europe at the national or pan-European scale (Demiroglu et al., 2019; Steiger and Scott, 28 2020; Morin et al., 2021), highlighting strong contrasts at the local (across ski resorts size and/or elevation 29 range, or local social or environmental context) and continental scales. Higher latitude and high elevation 30 locations generally exhibit delayed declines in snow reliability compared to lower latitude and lower- 31 elevation locations (high confidence), consistent with assessment conclusions reached in SROCC (Hock et 32 al., 2019). In general, climate change impacts and risks to ski tourism are found to be spatially 33 heterogeneous, within and across local and international markets, with potential for significant disruptions to 34 related socio-economic sectors due to a growing mismatch between ski area supply and skier demand in the 35 coming decades (Fang et al., 2019; Hock et al., 2019; Steiger et al., 2020a) (high confidence). These 36 disruptions are plausible, even though a fraction of current ski resorts could technically be able to operate 37 under comparatively favourable locations (elevation, latitude) and operating models (business models, socio- 38 cultural assets and conditions, governance) (Steiger et al., 2020b). | Heritage | 3510 - 3510 |
| IPCC | IPCC_AR6_WGII_Full_Report | 46 Projected changes in ice and snow-melt, as well as seasonal increases in extreme rainfall and permafrost 47 thaw, will favour chain reactions and cascading processes which can have devastating downstream effects 48 well beyond the site of the original event (Cui and Jia, 2015; Beniston et al., 2018; Terzi et al., 2019; Vaidya 49 et al., 2019; Shugar et al., 2021) (high confidence). The incidence of disasters is projected to increase in the 50 future due to some hazards becoming more pervasive, with an increase in the exposure of people and 51 infrastructure with future environmental and socio-economic changes either contributing to reduce or 52 enhance these disaster risks (Klein et al., 2019b) (medium confidence). | Heritage | 3510 - 3510 |
| IPCC | IPCC_AR6_WGII_Full_Report | 42 43 CCP5.3.2.4 KR4: Risk of Intangible Losses and the Loss of Cultural Values 44 45 The risk of intangible losses and loss of cultural values is associated with the decline of ice and snow cover 46 and temperature increase, as well as the increase in intangible harm from hazards such as floods and 47 droughts (high agreement, medium evidence) (Diemberger et al., 2015; Jurt et al., 2015; Vuille et al., 2018; 48 Tschakert et al., 2019; Vander Naald, 2020). Losses are intangible because they characterise aspects which 49 are difficult to quantify, i.e. loss of identity, loss of self-reliance, loss of rituals and traditions and place 50 attachment (Allison, 2015; Baul and McDonald, 2015; Motschmann et al., 2020a; Schneiderbauer et al., 51 2021). A global systematic analysis of case studies shows that this risk is more prevalent in the Andes, the 52 Himalaya and the Alps (Tschakert et al., 2019). Often mentioned across studies is the loss of intrinsic 53 memories and culture related to changes in world heritage landscapes and iconic sites (Jurt et al., 2015; 54 Sherry et al., 2018; Bosson et al., 2019). Changes in the hazard landscapes are also reported to contribute to 55 the loss of peace of mind and loss of well-being (Diemberger et al., 2015). Overall, there is limited evidence 56 but medium agreement that the risk of intangible losses and the loss of cultural identity will rapidly increase 57 and that consequences will go from reversible damage to irreversible losses (Tschakert et al., 2019). | Heritage | 3514 - 3514 |
| IPCC | IPCC_AR6_WGII_Full_Report | 36 37 Mountains are the home of many cultures and diverse Indigenous knowledge and local knowledge (systems), 38 which can and do provide strong support for place-based integrated adaptation and mitigation strategies 39 (Merino et al., 2019). Indigenous knowledge and local knowledge reinforce community adaptive capacity, 40 yet governance structures and processes, including the deliberate design and implementation of climate 41 policy, can constrain that capacity from being realised (Hill, 2013; McDowell et al., 2014; Wyborn et al., 42 2015; Klepp and Chavez-Rodriguez, 2018; Lavorel et al., 2019) (high confidence). Communities, 43 particularly poor and remote mountain communities, are vulnerable to climate change and there is a need for 44 capacity building in research, policy development and implementation for pursuing climate resilient 45 development (Manton and Stevenson, 2014). Climatic stressors and socio-economic changes are changing 46 traditional genderscapes in mountain communities (Goodrich et al., 2019). There is increasing evidence on 47 the roles that gendered diversity in knowledge, institutions, and everyday practices can play in addressing 48 barriers and creating opportunities for achieving resilience, adaptive capacity and sustainability in societies 49 (Gioli et al., 2014; Ravera et al., 2016; Su et al., 2017; Udas et al., 2018; Goodrich et al., 2019; Sujakhu et 50 al., 2019). | Heritage | 3518 - 3518 |
| IPCC | IPCC_AR6_WGII_Full_Report | 26 27 The availability of freshwater is a function of water supply and water demand, with the latter being 28 determined by sectors such as agriculture, energy, industry, or domestic use, as well as by competition 29 between these sectors. Formal and informal water extraction and use prevail, and competition includes issues 30 of inequalities, and power relations and asymmetry. Consequently, the effects of climate change on water 31 resources, people and ecosystems are strongly modulated and often exacerbated by socio-economic 32 development and related water resource management. For example, increasing frequency and intensity of 33 droughts in the European Alps, combined with decline and seasonal shifts of river runoff from snow and 34 glacier melt, is expected to result in growing competition between different sectors, such as hydropower, 35 agriculture, and tourism. Similar developments are projected or have already been observed in many other 36 mountain regions. This situation calls for strengthening and improving negotiation formats for water 37 management that are transparent, equal, and socially and environmentally just. Management of water 38 demand and strategies that entail multiple uses of water will become increasingly important in this context. | Heritage | 3522 - 3522 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 9 This is of relevance in mountains, where disaster risk is influenced by population growth, induced 10 displacements, land-use changes and inefficient water distribution systems. For example, current trends 11 suggest that more people are settling in exposed locations, with more infrastructure being built and activities 12 such as tourism and recreation being promoted, exacerbating this exposure. | Heritage | 3523 - 3523 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 42 43 Mountain regions cover about a quarter of the Earth's land surface, scattered around the globe and may 44 support a wide range of climates within short horizontal distances. Mountains have experienced above- 45 average warming, and this trend is expected to continue. Mountains provide a variety of goods for people, 46 are home to many Indigenous Peoples and are attractive for tourism and recreational activities. Mountain 47 regions support many different ecosystems and some are very species rich. Mountain regions can be vast and 48 diverse, and climate change and impacts on ecosystems vary greatly depending on location. | Heritage | 3523 - 3523 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 9 Other processes creating stresses on mountain ecosystems are direct human impacts, such as the influence of 10 grazing, tourism, air pollution and nitrogen deposition on alpine vegetation. In some cases, these impacts can 11 be so large on the goods and services provided by alpine ecosystems, that they can overshadow the effects of 12 climate change or exacerbate its effects. | Heritage | 3524 - 3524 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 16 Treelines have moved up in the last 30-100 years in many mountain regions, including e.g. Andes, Urals and 17 Altai. At the same time, since the 1990s, treelines responses in different parts of the Himalaya have been 18 highly variable, in some places advancing upslope, in others demonstrating little change, and in others 19 moving downward. This can be explained by site-specific complex interactions of the positive effect of 20 warming on tree growth, drought stress, change in snow precipitation, land-use change, especially grazing, 21 and other factors. Treelines are affected by land use and management around the globe and changing land- 22 use practices can supersede climate change effects in some mountain regions. An upward shift in elevation 23 of bioclimatic zones, decreases in area of the highest elevation zones, and an expansion of the lower zones 24 can be expected by mid-century, for examples in regions such as the Himalaya. | Heritage | 3524 - 3524 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 29 The appeal and feasibility of mountains for tourism and recreation activities are also affected by climate 30 change. | Heritage | 3524 - 3524 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 8 9 The polar regions, notably the Arctic and maritime Antarctic, are experiencing impacts from climate 10 change at magnitudes and rates that are among the highest in the world, and will become profoundly 11 different in the near-term future (by 2050) under all warming scenarios (high confidence). In the 12 Arctic, accelerated sea-ice loss (particularly during summer), increased permafrost thaw and extreme high 13 temperatures have substantially impacted marine, freshwater and terrestrial sociological-ecological systems 14 (very high confidence). Multiple physical, ecological and societal elements of polar regions are approaching 15 a level of change potentially irreversible for hundreds of years, if not millennia (high confidence). Evidence 16 of borealization of terrestrial and marine systems is emerging (high confidence), and cascading impacts are 17 on-going and widespread yet challenging to quantify fully due to complexity and lags in ecological 18 expression of change. Loss of multi-year sea-ice and the occurrence of a seasonally ice-free Arctic Ocean by 19 the middle of this century will result in substantial range contraction, if not the disappearance of several 20 Arctic fish, crab, bird and marine mammal species, including possible extinction of seals and polar bears in 21 certain regions (high confidence). In the Arctic, permafrost thaw and snowfall decrease lead to profound 22 hydrological changes, an overall greening of the tundra and regional browning of tundra and boreal forests 23 (high confidence). (CCP6.1; Table CCP6.1; Table CCP6.2; CCP6.2.1; CCP6.2.2; Table CCP6.5) 24 25 Contractions of the polar climate zones lead to distribution shifts and changes in food webs, induce 26 declines in many species (medium confidence) with impacts on subsistence harvests and commercial 27 fisheries, and threaten global dependence on polar regions for substantial marine food production 28 (high confidence). Climate change has induced food web changes resulting in population declines in polar 29 seabirds, including penguins, and marine and terrestrial mammals (high confidence). Globally and regionally 30 important harvested fish and invertebrate species are also contracting ranges and declining productivity, 31 including Pacific cod, salmon, snow and king crab in the Arctic and krill in the Antarctic (medium 32 confidence), with implications for global food systems (high confidence). (Table CCP6.2; CCP6.2.1; 33 CCP6.2.3; Table CCP6.3; Table CCP6.4) 34 35 Loss of sea-ice is rapidly expanding opportunities, but also increasing risks for shipping and other 36 economic industries in polar regions (very high confidence). Reduced sea-ice enables greater access to 37 high-latitudinal seas for industries, such as fisheries, shipping, tourism (very high confidence) and Arctic 38 maritime trade and resource extraction (medium confidence). Navigational risks have grown due to 39 increasingly mobile multi-year ice, poor hydrographic charting in newly open areas, and limited weather, 40 water, ice, and climate data and services (high confidence). Cascading risks from polar shipping growth 41 include increased air emissions, underwater noise pollution, disruption to subsistence hunting and cultural 42 activities in the Arctic (high confidence) and potential for invasive marine species and geopolitical tensions 43 (medium confidence). (Table CCP6.3; CCP6.2.4; Box CCP6.1; Table CCP6.5; Table CCP6.6) 44 45 Increased permafrost thaw and flooding will disrupt economically important transportation and 46 supply-chain infrastructure to remote Arctic settlements (high confidence), increasing risks to 47 economies, Arctic tourism and tourism to cultural heritage sites (medium confidence). Arctic permafrost 48 thaw is projected to impact most infrastructure by the middle of this century, impacting millions of people 49 and their economies, and costing billions in damages (high confidence). (CCP6.2.3; CCP6.2.4; Box CCP6.1; 50 CCP6.2.5; CCP6.3.1; Table CCP6.5; Table CCP6.6) 51 1 In this Report, the following summary terms are used to describe the available evidence: limited, medium, or robust; and for the degree of agreement: low, medium, or high. A level of confidence is expressed using five qualifiers: very low, low, medium, high, and very high, and typeset in italics, e.g., medium confidence. For a given evidence and agreement statement, different confidence levels can be assigned, but increasing levels of evidence and degrees of agreement are correlated with increasing confidence. | Heritage | 3549 - 3549 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Cross-Chapter Paper 6 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP6-3 Total pages: 66 1 Climate change increasingly threatens many facets of Arctic livelihoods, culture, identity, health and 2 security, particularly for Indigenous Peoples (very high confidence). It has negatively impacted mental 3 health and increased risks of injury, food insecurity and foodborne and waterborne disease, with risks 4 amplified for those reliant on the environment for subsistence, livelihoods and identity (high confidence). | Heritage | 3549 - 3550 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 5 Permafrost thaw, sea-level rise and reduced sea-ice protection have already damaged or destroyed many 6 cultural heritage sites in some Arctic regions (very high confidence) and are projected to continue across all 7 Arctic regions (very high confidence). (CCP6.2.3; Table CCP6.3; CCP6.2.4; CCP6.2.5; CCP6.2.6; Figure 8 CCP6.3; Box CCP6.2; CCP6.3.1; Table CCP6.5; Table CCP6.6) 9 10 Adaptation 11 12 Adaptations to manage climate change impacts and risks in polar regions are urgently needed (very 13 high confidence), but implementation is uneven (high confidence), limits to adaptation are high and 14 maladaptation is probable (high confidence). | Heritage | 3550 - 3550 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 47 48 Development of robust pathways for climate resilience in the Arctic can be accelerated by adaptation 49 strategies and governance that reflect local conditions, cultures and adaptive capacities of 50 communities and sectors (high confidence). Effectiveness of adaptation strategies will be enhanced by 51 accounting for the geographic, climatic, ecological and cultural uniqueness of the polar regions (medium 52 confidence). Colonialism can inhibit the development of robust climate adaptation strategies, and exacerbate 53 climate risks (very high confidence). Inclusive decision-making in establishing climate adaptations can foster 54 resilience, reflect the unique environmental, cultural, and economic imperatives of the region and support 55 both market-based and sharing economies (high confidence). (Box CCP6.2; Table CCP6.6; CCP6.3.2; 56 CCP6.4) 57 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Cross-Chapter Paper 6 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP6-4 Total pages: 66 1 Indigenous self-determination in managing climate change impacts, adaptations, and solutions can 2 accelerate effective robust climate-resilient development pathways in the Arctic (very high confidence). | Heritage | 3550 - 3551 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 10 11 These changes are causing a suite of direct and cascading risks for all polar ecosystems with larger effects to 12 date in the Arctic than the Antarctic (high confidence), due to larger and regionally more consistent physical 13 changes (Figure CCP6.2, Table CCP6.1; Chapter 3) (Meredith et al., 2019; Ranasinghe et al., 2021). In the 14 Arctic, these changes affect every sector of society, impacting its 4,000,000 inhabitants, including 400,000 15 Indigenous People. The Antarctic has no permanent human settlements; however, many nations conduct 16 field research, operate seasonal and permanent stations and have an interest in the management of the region 17 (Hughes et al., 2018; Grant et al., 2021). During summer, when Antarctic science, tourism and fishery 18 activities are greatest, 4,400 people live there, whereas only 1,100 people live there over winter (Meredith et 19 al., 2019). Although adaptation is occurring in polar regions, it is uneven and sporadic and does not meet the 20 risks posed by future climate change. Indigenous knowledge-based solutions, inclusive ecosystem-based 21 policies and integrated technologies demonstrate the potential to effectively address climate change impacts 22 across scales and sectors; yet implementation barriers remain (CCP6.4.1). | Heritage | 3552 - 3552 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 40 Climate change continues to alter vegetation and attendant biodiversity, with divergent regional trends across 41 the Arctic due to disparities in local conditions and changes in growing seasons (Zhu et al., 2016; Taylor et 42 al., 2020). Warming facilitates woody vegetation growth in northeastern Siberia, western Alaska, and 43 northern Quebec (Song et al., 2018; García Criado et al., 2020), as well as a northward expansion of shrub 44 vegetation and sub-Arctic and boreal species (Davidson et al., 2020). | Heritage | 3562 - 3562 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 45 46 Further evidence shows that warming and changes to the Arctic hydrologic cycle increase the risk of wildfire 47 (medium confidence) (Mustonen and Shadrin, 2021). Both the frequency of and the area burned by wildfires 48 during recent years are unprecedented compared to the last 10,000 years (high confidence) (Meredith et al., 49 2019; Irannezhad et al., 2020). Fire risk levels are projected to increase across most tundra and boreal 50 regions, and interactions between climate and shifting vegetation (Song et al., 2018) will influence future fire 51 intensity and frequency (medium confidence) (Curtis et al., 2018). | Heritage | 3562 - 3562 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 44 45 46 CCP6.2.3 Food, Fiber, and other Ecosystem Products 47 48 Food and fiber production underpins regional identities, cultures, and communities of practice and place in 49 polar regions, are vital to local and distant economies (Table CCP6.4) and they represent for fisheries a 50 critical source of global nutrition and food security (Hicks et al., 2019). Since SROCC, there is further 51 evidence that climate change alterations of polar ecosystems increasingly challenge production of, and 52 access to, sufficient, healthy, and nutritious food, posing risks to future food and nutritional security within 53 and beyond polar regions (high confidence). | Heritage | 3563 - 3563 |
| IPCC | IPCC_AR6_WGII_Full_ Report | (Furberg et al., 2011; Uboni et al., 2020; Mustonen and Shadrin, 2021) Sea-ice; winds; visibility Loss of multiyear “mother ice”, declines in seasonal sea-ice thickness and stability, as well as changes in winds and visibility have impacted the availability of, and access to, subsistence resources (high confidence) and have increased interactions between coastal communities and shipping, tourism and commercial fisheries, which directly impact human safety and well-being in Arctic communities (high confidence). | Heritage | 3564 - 3564 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 24 25 Large-scale commercial fisheries are expected to continue to operate in polar regions (high confidence) 26 (Barange et al., 2018; Cavanagh et al., 2021; Grant et al., 2021), and will shift poleward (high confidence) 27 toward geopolitical and management boundaries (high confidence) (CCP6.3.2.3; Table CCP6.6). Warming 28 and climate impacts will continue to impact transboundary stocks and increase the potential for conflict in 29 fisheries management (Pinsky et al., 2018; Mendenhall et al., 2020; Palacios-Abrantes et al., 2020; Sumaila 30 et al., 2020). Increased distances from ports to redistributed fishing grounds, as well as increased frequency 31 of storms and other extreme events are expected to increase risks and costs for fishery operations (medium 32 confidence) and impact shore-based infrastructure and emergency response services (CCP6.2.4). Observed 33 and expected increases in mobile ice combined with abrupt wind can create major hazards for fish operators 34 in Antarctica and the Arctic, with consequences to human safety and total revenue (Dawson and et al., 2017; 35 Barber et al., 2018; Grant et al., 2021). There will be increased demand for new port infrastructure across the 36 Arctic (high confidence); new ports have already been proposed for the northern Bering Sea, and small craft 37 harbour investments are being considered across Arctic Canada and Greenland. Ecosystem-based 38 management, increasing diversity and flexibility in harvest portfolios, access to high-resolution ecological 39 forecasts and projections, and climate-informed advice will promote adaptation and climate resilience in 40 fisheries (Dawson and et al., 2017; Brooks et al., 2018; Karp et al., 2019; Hollowed et al., 2020). Coupling 41 adaptation measures with global carbon mitigation strategies substantially decreases climate change risks to 42 polar fisheries (very high confidence) (CCP6.3). | Heritage | 3566 - 3566 |
| IPCC | IPCC_AR6_WGII_Full_ Report | (Piñones and Fedorov, 2016; Klein et al., 2018) 1 2 3 CCP6.2.4 Economic Activities 4 5 Climate change presents significant risks to economic activities in the polar regions (very high confidence) 6 and simultaneously enables development possibilities for fisheries (CCP6.2.3.3), agriculture (CCP6.2.3.2), 7 the sharing and subsistence economy (CCP6.2.3.1) (SMCCP6.2) (high confidence), maritime trade (Box 8 CCP6.1), natural resource development (CCP6.2.4.1) (medium confidence), tourism (CCP6.2.4.2), and 9 transportation (including shipping) (CCP6.2.4.3; FAQ CCP6.2). Hundreds of billions of dollars are expected 10 to be invested in the polar regions in the next several decades (Lloyd's, 2012; Barnhart et al., 2016; 11 Pendakur, 2017; Tsukerman et al., 2019) and, as this unfolds, there are opportunities to simultaneously 12 implement adaptation strategies that support climate resilient development pathways in line with self- 13 determination for Indigenous Peoples and local communities and locally derived visions of successful 14 adaptation and development (CCP6.3.2, CCP6.4.3) (Jorgenson, 2007; Ritsema et al., 2015; Ready and 15 Power, 2017; Larsen and Petrov, 2020). | Heritage | 3568 - 3568 |
| IPCC | IPCC_AR6_WGII_Full_ Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Cross-Chapter Paper 6 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP6-22 Total pages: 66 1 2 3 CCP6.2.4.1 Changing access to natural resources with consequences for safety, economic development and 4 climate mitigation 5 6 Climate change is improving access to natural resources in the Arctic with consequences for human safety 7 (high confidence), economic development (very high confidence) and global mitigation efforts (medium 8 confidence). Reductions in sea-ice combined with improved extraction and transportation technologies have 9 increased accessibility to natural resources across the Arctic (Eliasson et al., 2017; Dawson et al., 2018b; 10 Stephen, 2018); a situation that could support continued global dependence on relatively cheap and abundant 11 fossil fuels resources and contribute to further warming. By 2040 (RCP4.5) it is expected that sea-ice will 12 have receded enough to make gas production technologically feasible in the European off-shore Arctic 13 (Petrick et al., 2017). However, increased sea-ice mobility, iceberg abundance, storm surge, and surface 14 wave action (Ng et al., 2018; Howell and Brady, 2019; Casas-Prat and Wang, 2020) will also increase risks 15 to ships servicing mines in a region that already exhibits disproportionately high accident rates (Council of 16 Canadian Academies, 2016) (CCP6.3.1, Table CCP6.1). Season lengths for ship-based support to mines and 17 extraction sites will increase with sea-ice change, while access via ice roads will decrease with warming 18 (Perrin et al., 2015; Council of Canadian Academies, 2016; Trofimenko et al., 2017; Southcott and Natcher, 19 2018). By 2050, climate change impacts to the Tibbitt to Contwoyto Winter Road servicing mines in the 20 northeastern region of the Northwest Territories, Canada could cost between $55 million to $213 million 21 CAD to maintain for a shorter period of time than at present (Perrin et al., 2015). Changes in submarine 22 permafrost, critical to mining infrastructure, such as pipelines and offshore infrastructure (Bashaw et al., 23 2016; Paulin and Caines, 2016), are expected to increase production costs and impact safety for workers 24 (Riedel et al., 2017). By mid-century, regardless of emissions scenario, it is expected that risks from 25 permafrost thaw will be disproportionately high for industrial infrastructure along major pipeline systems in 26 Alaska and natural gas extraction areas in the Yamal-Nenets region in northwestern Siberia, Russia (Hjort et 27 al., 2018). | Heritage | 3568 - 3569 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 28 29 CCP6.2.4.2 Changing demand, opportunities and risks for polar tourism 30 31 Climate change has increased risks to, and demand for, polar tourism experiences related to increased 32 maritime accessibility (high confidence), lengthening of warm weather season lengths (very high confidence) 33 and development of a 'last chance tourism market' (medium confidence). Reductions in sea-ice extent have 34 facilitated increased access for polar cruising (Dawson et al., 2018b; Stewart et al., 2020). Demand for Arctic 35 cruises has increased by 20.5% over the past five years and resulted in 27.2 million passengers in 2018 36 (Shijin et al., 2020). In the Antarctic, tourist numbers increased by 27% from 1992-2018 and attracted 37 75,000 visitors in 2019-2020 (IAATO, 2020; Shijin et al., 2020), making it the largest economic sector in the 38 entire region (Stewart et al., 2020). The recent increase in polar tourism is due in part to the development of 39 a niche market called 'last chance tourism', which involves explicitly marketing vulnerable or vanishing 40 destinations or features (i.e., glaciers, polar bears, landscapes) and encouraging tourists to see them 'before 41 they are gone' (Dawson et al., 2018a; Groulx et al., 2019). However, tourism development opportunities will 42 also contend with ongoing risks related to the COVID19 pandemic, which halted tourism globally in 2020- 43 2021 (Frame and Hemmings, 2020; Lorenzo et al., 2020), as well as those related to increased climatic risks 44 limiting participation and reducing safety and security. By 2100 under RCP8.5, snow cover season length 45 suitable for winter recreational activities is projected to decrease by 21−49% in West Greenland (Schrot et 46 al., 2019). Reduced sea-ice and snow cover creates hazards for and could limit dog sledding, cross country 47 skiing, snowmobiling and floe edge tours, with limited adaptation strategies available for low elevation areas 48 (Stephen, 2018; Palma et al., 2019). | Heritage | 3569 - 3569 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 18 19 The polar seas have captured the imagination of global nations for centuries for its natural resource, 20 tourism, scientific, and maritime trade potential. As the polar regions are warming at two to three times the 21 rate of the global average leading to rapid reductions in sea-ice extent and thickness, international attention 22 has been reinvigorated and investments are being made by Arctic and non-Arctic nations alike with a view to 23 utilize newly accessible seaways. Between 2013 and 2019 ship traffic entering the Arctic grew by 25% and 24 the total distance travelled increased by 75%. Similar shipping growth trends are evident in the Antarctic 25 albeit to a lesser extent. Expected growth in Arctic shipping will influence a suite of cascading 26 environmental and cultural risks with implications for Indigenous Peoples. | Heritage | 3570 - 3570 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 27 28 29 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Cross-Chapter Paper 6 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP6-24 Total pages: 66 1 Figure FAQ CCP6.2.1: Projected operational accessibility along Arctic maritime trade routes (Northwest Passage, 2 Transpolar Route, and Northern Sea Route) under future warming (left) and observed increases in commercial ship 3 traffic along the routes from 2012-2019 4 5 6 There has been debate among shipping stakeholders, rightsholders, and experts about the extent to which 7 climate change and sea-ice change is directly influencing increases in shipping activity in the polar regions 8 relative to other social, technological, political, and economic factors such as commodity prices, tourism 9 demand, global economic trends, infrastructure support, and service availability. Understanding the 10 connection between climate change and polar shipping activity will allow for more reliable projections of 11 possible future traffic trends and will aid in identifying appropriate adaptation and infrastructure needs 12 required to support future management of the industry. Recent studies have observed increasing statistical 13 correlations between sea-ice change and shipping trends in the polar regions and many have concluded that 14 although economic factors remain the main driver of shipping activities, followed by infrastructure 15 availability, climate change does indeed play a varying but important role in influencing operator intentions. | Heritage | 3570 - 3571 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 49 50 There are three identified trade routes in the Arctic: Northern Sea Route (NSR), Northwest Passages (NWP), 51 and the Transpolar Sea Route (TSR). Over the last decade economic trends and reductions in sea-ice have 52 facilitated significant increases in ship traffic in the NSR (Aksenov et al., 2017; Li et al., 2020), including a 53 79% increase in total transit tonnage from 2010 to 2017 (Babin et al., 2020) related mostly to domestic 54 resource development. Relative to an early 21st century baseline, it is expected that the NSR will become 55 18% more accessible by mid-century (Stephenson et al., 2013) and could navigable even for non-ice 56 strengthened vessels for 101-118 days annually by 2050 and 125-192 days by 2100 (Khon et al., 2017). The 57 NWP has experienced a tripling of km travelled by ships since 1990, attributed mostly to resource extraction ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Cross-Chapter Paper 6 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP6-25 Total pages: 66 1 and increases in tourism opportunities (Johnston et al., 2017; Dawson et al., 2018a). The NWP could become 2 30% more accessible by 2050 compared to current conditions (Stephenson et al., 2013). Before 4°C global 3 warming above pre-industrial, re-supply vessels (Polar Class 7) in the western NWP could gain an additional 4 month of operating time, whereas the eastern NWP could gain just two weeks (Mudryk et al., 2021) due to 5 the dynamic import of mobile and hazardous ice from the Arctic Ocean (Haas and Howell, 2015; Howell and 6 Brady, 2019). Comparatively, the TSR has historically only been viable for nuclear icebreakers, submarines, 7 and occasional military and scientific activity due to thick multiyear ice regimes (Bennett et al., 2020). | Heritage | 3571 - 3572 |

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| IPCC | IPCC_AR6_WGII_Full_Report | 43 44 Climate change has important intangible loss and damage implications in the Arctic, with negative impacts 45 ranging from livelihoods to spirituality to solastalgia (i.e. distress caused by environmental change) (Cunsolo 46 and Ellis, 2018; Middleton et al., 2020b; Sawatzky et al., 2020; Mustonen and Shadrin, 2021). Permafrost 47 thaw, SLR, and reduced sea-ice protection also presents risk to socio-cultural assets, including heritage sites 48 in all Arctic regions (very high confidence) (Friesen, 2015; Hollesen et al., 2016; Radosavljevic et al., 2016; 49 O'Rourke, 2017; Hillerdal et al., 2019; Fenger-Nielsen et al., 2020; Jensen, 2020). A large number of 50 archaeological sites are at risk from climate change in southwest Greenland; Yukon's Beaufort coast, 51 Canada; and Auyuittuq National Park Reserve, Nunavut, Canada (Westley et al., 2011; Hollesen et al., 2018; 52 Irrgang et al., 2019; Fenger-Nielsen et al., 2020). Siberian nomadic reindeer herding and fishing livelihoods 53 are vulnerable to permafrost thaw, which alters northern landscapes and lakes, as well as rain-on-snow 54 events, and rapidly changes landscapes and terrestrial and aquatic habitats (Mustonen and Mustonen, 2016; 55 Brattland and Mustonen, 2018; Mustonen and Huusari, 2020) (CCP6.2.2). The intangible loss and damage to 56 nomadic cultures could cascade to losses of identity and social challenges (CCP6.2.6; Chapter 13). | Heritage | 3573 - 3573 |
| IPCC | IPCC_AR6_WGII_Full_Report | 51 52 Climate change has negative, widespread and cumulative impacts on mental health in the Arctic, particularly 53 for Indigenous Peoples (very high confidence) (Figure CCP6.3). Climate-sensitive mental health outcomes 54 are complex, overlapping, and interrelated, and have multiple direct and indirect pathways stemming from: 55 acute (e.g., major storms, flooding, wildfires) and chronic (e.g., temperature increases, sea-ice loss, 56 permafrost thaw) environmental conditions, and resulting disruptions to livelihoods, culture, food systems, 57 social connections, health systems, and economies (Cunsolo Willox et al., 2013a; Cunsolo Willox et al., ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Cross-Chapter Paper 6 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP6-28 Total pages: 66 1 2013b; Cunsolo Willox et al., 2014; Beaumier et al., 2015; Durkalec et al., 2015; Hamilton et al., 2016; 2 Clayton et al., 2017; Dodd et al., 2018; Jaakkola et al., 2018; Markon et al., 2018; ITK, 2019; Minor et al., 3 2019; Middleton et al., 2020a; Middleton et al., 2020b; Feodoroff, 2021). | Heritage | 3574 - 3575 |
| IPCC | IPCC_AR6_WGII_Full_Report | 7 8 Indigenous knowledge systems are diverse among and within Arctic Indigenous Peoples, and reflect deep 9 and rich knowledge that situates and contextualizes values, traditions, governance, and practical ways of 10 adapting to the ecosystem over millennia (Raymond-Yakoubian et al., 2017; Brattland and Mustonen, 2018). | Heritage | 3577 - 3577 |
| IPCC | IPCC_AR6_WGII_Full_Report | 25 26 Climate change, nomadic lifestyles, and preservation of traditions 27 28 Perspectives from the Yukaghir Council of Elders and Russian Association of Indigenous Peoples, Russia 29 30 Climate change threatens reindeer herding, hunting, fishing, and gathering, which form the basis of Siberian 31 Indigenous societies. Nomadic herding lifestyle is premised on Indigenous knowledge which has 32 accumulated over millennia. IK, including the ability to predict weather, has played a substantial role in the 33 adaptation to the extreme conditions. According to Shadrin (2021) present, rapid changes are changing 34 Indigenous concepts of reality - they are increasingly finding themselves in situations where their experience 35 and knowledge cannot help them. An Elder in Northeast Siberia explained that "nature does not trust us 36 anymore" (Mustonen and Shadrin, 2021). | Heritage | 3577 - 3577 |
| IPCC | IPCC_AR6_WGII_Full_Report | 56 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Cross-Chapter Paper 6 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP6-31 Total pages: 66 1 Climate change impacts Indigenous Peoples' health. Degradation of the quality of surface waters has 2 increased, resulting from new floods and the thawing of permafrost, which increases risk of gastrointestinal 3 diseases (CCP6.2.8). The 2007 flood on Alazaya river was of special importance and was locally identified 4 to have produced the first regional "climate refugees" (Mustonen and Shadrin, 2021). Warming has 5 expanded the distribution of new disease-carrying insects and ticks into new territories (Mustonen and 6 Shadrin, 2021). Ancient cemeteries and campsites, as well as the burial sites of reindeer, become dangerous 7 as permafrost thaws and coastal erosion proceeds. | Heritage | 3577 - 3578 |
| IPCC | IPCC_AR6_WGII_Full_Report | 8 9 Traditional food security is under threat. Permafrost-based storage facilities have deteriorated (CCP6.2.6) 10 (Mustonen and Shadrin, 2021). There is an increase in the number of people who are forced to abandon the 11 consumption of raw fish. As a result, the likelihood of losing cultural traditions is growing. These combined 12 climate change impacts result in loss of Indigenous knowledge and nomadic lifestyles, thus, losing important 13 aspects of their identity as distinct Indigenous Peoples (Mustonen and Shadrin, 2021). | Heritage | 3578 - 3578 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 42  43 The extraordinary developments in the field of Indigenous Knowledge have crystallized the main tenant of   44 interaction with the natural world that is "integral to a cultural complex that also encompasses language,   45 systems of classification, resource use practices, social interactions, ritual and spirituality" (UNESCO, 46 2017). Inuit have used their knowledge of the land and coastal seas to design technology, monitoring   47 systems (Atlas of Community-Based Monitoring in a Changing Arctic, 2021), and new hunting routes that   48 respond to the changes they face (Inuit Circumpolar Council, 2017; Nunavut Climate Change Center, 2018; 49 SIKU, 2020). Such examples of 'adaptation success' across Inuit Nunaat have been showcased and   50 celebrated nationally and internationally (Youth Climate Report, 2019) and all are underpinned by Inuit   51 knowledge and pivot on their right to self-determination. This is also embodied, for example, in Canada, the   52 National Inuit Climate Change Strategy outlines the collective Canadian Inuit plan for climate action,   53 centering on Inuit-determined priorities to protect their culture, language, and way of life, and guiding   54 partners in how to work with Inuit on implementing this strategy (ITK, 2019). Their action on adaptation   55 also spans scales from local to international. As far back as 1977, Inuit have been organized and involved at   56 the international level. Inuit were present at the Rio Earth Summit and have participated in diverse but   57 interrelated United Nations conventions to protect their homelands (e.g., UNFCCC, CBD, Stockholm   ACCEPTED VERSION   SUBJECT TO FINAL EDITS<br>FINAL DRAFT Cross-Chapter Paper 6 IPCC WGII Sixth Assessment Report  Do Not Cite, Quote or Distribute CCP6-32 Total pages: 66  1 Convention). This history gives us unique insight and positions us as both leaders and partners with the   2 ability to engage directly with governments, business, and others. | Heritage | 3578 - 3579 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 8  9 Central to their significant capacity to adapt is that it is done in recognition of the need to move beyond   10 adaptation. Indeed, Inuit-led adaptation action is founded on the intention of contributing to and moving   11 towards reformation and eventual transformation of systems to create a 'climate resilient' Arctic. This   12 concept has surfaced in academic climate change literature and discussion and has begun to filter into the   13 climate policy arena, especially within the context of the current COVID-19 pandemic that challenges us all   14 to think about our world differently. With acknowledgement that reform and transformation is needed, the 15 question remains, 'What does this look like?'   16  17 Inuit have an answer. System reform and transformation is grounded in self-determination. It is based in a 18 human rights framework and rooted in Indigenous knowledge and culture. It recognizes and respects   19 interconnectedness and builds this into solutions. It demands collaboration and true partnership towards   20 action. And it comes from thinking big and across scales. Shaping this change calls for willingness and   21 support to rethink the current economic and governance models that have failed us. For example,   22 decentralizing governance and management, while it remains largely unconventional, has been shown to   23 create some of the strongest systems we have. This is, in a large part, due to the way in which   24 decentralization places more value and responsibility on the 'self' in self-determination. Decentralized   25 processes in the Arctic have Indigenous knowledge holders playing a key and lead role in determining,   26 defining, deciding how to work towards positive change. | Heritage | 3579 - 3579 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | (non-climatic factors) Coastal settlements (CCP6.2.5) Change in extent of sea�ice with more storm surges, thawing of permafrost, sea level rise, and coastal erosion Local leadership and community-led initiatives to initiate and drive processes, responsive agencies, established processes for assessments and planning, geographic options Increasing number of communities needing relocation (medium confidence), rising costs for mitigating erosion (high confidence) Limitations of government budgets, other disasters that may take priority, policies deficiencies for addressing mitigation and relocation Human health (CCP6.2.6) Increased food insecurity, waterborne disease, emerging pathogens, injury and death, and negative mental health outcomes Resources to support public programs; Indigenous self�determination; access to technology; supporting Indigenous knowledge systems; interdisciplinary and integrated decision�making The intersection of social determinants of health will modify or mediate climate change impacts on health (very high confidence) Underlying health conditions, advances in diagnosis and treatment, and other health system shocks (e.g., COVID) ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Cross-Chapter Paper 6 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP6-37 Total pages: 66 Transportation (aviation, rail, road, ice roads) (CCP6.2.4.3) Permafrost thaw, sea�ice change, storm surge, coastal erosion, changing precipitation patterns (ice pellets, hail), and extreme events create risks to transportation infrastructure with consequences to navigation, economics, safety, and security Financial and human resources for: climate resilient infrastructure research, development and implementation; improved weather, water, ice and climate forecasting at appropriate scales; improved communications infrastructure; local search and rescue Limits to adaptation exist (high confidence), but strategic investments in technologically innovative infrastructure that offers mitigation co-benefits will greatly enhance adaptation effectiveness (very high confidence) Level of local, regional, and national infrastructure development, commitment of national and state level government to sustainable development pathways, global economic and political trends, commodity prices, unforeseen system shocks Shipping (Box CCP6.1; FAQ CCP2) Sea-ice reduction leading to increased shipping related to trade, tourism, fisheries, resource development, and re-supply with cascading risks from ships such as: increased under-water noise, potential introduction of invasive species, fuel spill risks, release of black carbon and air emissions, impacts to cultural resources, implications for subsistence hunting and food security, increased accidents and incidents Financial support for ship-building technologies (e.g., low emission fuels, propulsion technologies, hull strength); development of robust multi-national agreements (in addition to existing agreements); inclusion of Indigenous Peoples in decision�making; investment in multi-national and longitudinal research on shipping impacts; and enhancing modern digital maritime charting Ship traffic will continue to grow in polar regions (high confidence) with Arctic trade routes becoming increasing accessible (very high confidence) albeit with more challenging navigation due to increases in mobile ice in the near�term compared to late century when ice is expected to diminish completely during the shipping season (high confidence) Geopolitical and sovereignty debates; shipping insurance premiums; global economic trends; commodity prices; national policies and politics; level of infrastructure investment; availability of search and rescue assets, and modern charting Infrastructure (CCP6.2.5) Loss and damage to infrastructure from permafrost thaw affecting stability of ground; coastal erosion; SLR Resources for assessments, mitigation, and where needed, relocation Increasing cost to maintain infrastructure and greater demand for technological solutions to prevent damages (high confidence) Strength of regional and national economies, other disasters that divert resources Non-renewable resource extraction (Arctic only) (CCP6.2.4.1) Reduced sea-ice improves access to non�renewable resources in remote Arctic regions, while warming temperature and thawing permafrost affect production levels, quality, and reliability and season length of ice roads leading to increased operational costs Investment in climate resilient infrastructure and low emission | Heritage | 3583 - 3585 |
| IPCC | IPCC_AR6_WGII_Full_ Report | Declines in catch impact livelihoods, coastal communities, and pose a risk to regional and global food and nutritional security (very high confidence) Changes in global demand for seafood, demand and markets, changes in gear, changes in policies affecting property rights. Changes due to offshore development and transportation Marine subsistence (CCP6.2.3; CCP6.2.3.1) Changes in species distribution and abundance (not all negative); impediments to access of harvesting areas especially sea-ice; increased interactions with shipping; safety; changes in seasonality; reduced harvesting success and process of food production (processing, food storage; quality); threats to culture and food security Systems of adaptive co�management that allow for species switching, changes in harvesting methods and timing, secure harvesting rights, communication and relationship building, co-production of knowledge Changes in distribution and abundance of resources combined with more regulations related to species at risk. Adaptation at the local, individual, and household level under low mitigation scenarios will be costly and possibly undermined by the scale and pace of change, including climate shocks and extreme events (medium confidence) Changes in cost of fuel, land use affecting access, food preferences, harvesting rights; colonialism, international agreements to protect vulnerable species Marine ecosystems (CCP6.2.1) Warming, sea-ice loss, ocean acidification resulting in poleward contraction of polar zones, invasive species introduction, displacement of polar species, and restructuring of food webs Reduce effects of external and compounding risks and increase application of ecosystem-based management to meet biodiversity and management goals. | Heritage | 3585 - 3585 |
| IPCC | IPCC_AR6_WGII_Full_ Report | Conservation of genetic diversity and biodiversity to preserve resilience, and Without institutional investment in sustaining climate resilience in ecosystems across sectors there is a high risk of failure (high confidence) Novel and expanding activities in ice free areas (shipping; fishing), energy development and mineral extraction, increased tourism, global markets and demand for polar resources, population growth and community ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Cross-Chapter Paper 6 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP6-39 Total pages: 66 supplementation and assisted migration may be needed relocation to coastal areas Terrestrial and Freshwater ecosystems (CCP6.2.2) Warming, hydrology changes (reduced ice on lakes and rivers, flooding, snow) and permafrost thaw lead to impacts on polar terrestrial and freshwater systems, food webs, the distribution of polar fish, implications for peat systems with consequent changes on dependent animal assemblages and increasingly favorable conditions for parasites and pathogens. | Heritage | 3585 - 3586 |

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| IPCC | IPCC_AR6_WGII_Full_Report | Novel and expanding activities in ice free areas (shipping; fishing), energy development and mineral extraction, increased tourism, global markets and demand for polar resources, population growth and community relocation to coastal areas 1 2 3 4 5 Figure CCP6.6: Assessment of feasibility and effectiveness of adaptation options by key risks in the polar regions 6 (Table CCP6.6) 7 ACCEPTED VERSION SUBJECT TO FINAL EDITS FINAL DRAFT Cross-Chapter Paper 6 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP6-40 Total pages: 66 1 2 The need for self-determination for Indigenous Peoples and local communities in decision-making and 3 cooperation across Arctic nations to manage a rapidly changing Arctic is increasingly recognized, 4 particularly in a shipping and wildlife management context where climate impacts will be transboundary and 5 multi-sectoral (Spence, 2017; Forbis and Hayhoe, 2018; Ford and Clark, 2019; Dawson et al., 2020) 6 (CCP6.2.6; Box CCP6.2). Effective Indigenous and community-led adaptation efforts have been 7 implemented across the Arctic to alleviate climate and non-climate stressors and build resilience through 8 restoration and conservation (Huntington et al., 2017; Brattland and Mustonen, 2018; Hudson and Vodden, 9 2020; Mustonen and Feodoroff, 2020; Uboni et al., 2020; Huntington et al., 2021). For example, Indigenous 10 knowledge and science has been used by the Skolt Sámi in Finland to attenuate warming, drought, and water 11 quality impacts on salmonids through restoration of spawning and nursery habitats in the Vainosjoki river 12 catchment (Brattland and Mustonen, 2018; Mustonen and Feodoroff, 2020; Ogar et al., 2020). This 13 ecological restoration of damaged habitats for fish represents community-led actions. In Aasiaat, 14 Greenlandic hunters have implemented community-based oceanographic and ecological monitoring to 15 convey Indigenous knowledge observations of rapid change to the government and scientists. A special 16 aspect of land use in the Russian North is the preservation of nomadic lifestyles of the Nenets and Chukchi 17 (Mustonen and Mustonen, 2016), and while these traditional economies have undergone rapid change due to 18 non-climate drivers, their land uses, observational frameworks and cultural matrixes remain of high 19 importance in the context of climate change. Endemic responses (self-agency from within the culture) and 20 Indigenous governance enable adaptation to the rapid and accelerating changes under way (Mustonen et al., 21 2018a). Therefore, community-based monitoring and inclusion of Indigenous knowledge in dialogue with 22 science has been an effective mechanism to detect and respond to climate change. | Heritage | 3586 - 3587 |
| IPCC | IPCC_AR6_WGII_Full_Report | 23 24 CCP6.3.2.2 Adaptation gaps 25 26 In a study of adaptation progress across the Arctic from 2004−2019, 233 cases of adaptation were 27 documented, with the majority of actions primarily behavioural and reactionary in nature and undertaken in 28 the subsistence harvesting sector, with resource management, and infrastructure and transportation other 29 prominent sectors where adaptation responses were documented to be occurring (Canosa et al., 2020). The 30 study found few changes in the profile of adaptation over time, except for an increase in responses being 31 motivated solely by climate impacts, and few cases of transformational change, although caution that a lack 32 of data on adaptation actions makes documenting trends challenging. Human health is generally under- 33 represented in adaptation initiatives, along with adaptations being developed within larger Arctic settlements 34 (Ford et al., 2014; Canosa et al., 2020), and in many sectors decisions continue to be made without explicit 35 inclusion of climate change impacts and risk in planning and design (high confidence) (Cherry et al., 2017; 36 Lauta et al., 2018; Meredith et al., 2019). There is limited evidence of transformational adaptation taking 37 place in the policy arena (e.g., U.S. Executive Order 13990, 2021), but many examples of how impacts and 38 responses to climate change have transformed social-ecological connections, traditions, markets, trade, and 39 livelihoods of Arctic residents and Indigenous Peoples (Ford et al., 2015). | Heritage | 3587 - 3587 |
| IPCC | IPCC_AR6_WGII_Full_Report | 13 14 There are significant limits to adaptation in the polar regions related to the rate of warming and cascading 15 changes that are occurring, which is equivalent to double and sometimes triple the global average depending 16 on the region (Bush and Lemmen, 2019; IPCC, 2021). The rapid pace of change, such as sea-ice loss, can 17 outpace ecological processes and induce substantial ecological shifts (CCP6.2)(medium confidence). The 18 speed of climate change in the Arctic limits options for adaptation in communities who rely on a narrow 19 resource base, when adaptation involves loss of culture and livelihoods, and when the costs of adaptation 20 makes it infeasible (medium confidence) (Ford et al., 2015), such as for reindeer herding (Table CCP6.6; 21 Figure CCP6.6; Figure CCP6.7) (Meredith et al., 2019). Adapting infrastructure in response to a rapidly 22 changing cryosphere will be limited by available technologies and the relatively higher costs associated with 23 updating infrastructure over vast polar regions (Schneider von Deimling et al., 2021). | Heritage | 3588 - 3588 |
| IPCC | IPCC_AR6_WGII_Full_Report | 32 33 [END FAQ CCP6.4 HERE] 34 35 36 CCP6.4 Climate Resilient Development Pathways 37 38 The polar regions are expected to experience many economic development opportunities as a result of 39 climate change, including increased accessibility for shipping and attractiveness for fisheries and tourism 40 (CCP6.2.3.1, CCP6.2.4). For polar regions, equitable climate resilient development requires diverse 41 perspectives in planning and implementation. In the Arctic, cultural, social and economic dimensions of 42 Indigenous Peoples and local communities are critical (Ritsema et al., 2015; Huntington et al., 2021). For 43 both poles, there are global cultural connections to polar systems (Roberts et al., 2021), along with important 44 global and local needs for sustained ecosystems and their services, in the face of diminishing polar zonal 45 conditions (Cavanagh et al., 2021; Murphy et al., 2021; Solomonsz et al., 2021). | Heritage | 3589 - 3589 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | 14 15 Many losses and damages within Indigenous contexts are not able to be monetized but can be profound, such 16 as loss of Indigenous languages (CAFF, 2013), loss of Indigenous knowledge associated with nomadic 17 lifestyles and cultures (Box CCP6.2), and loss of geographical knowledge associated with an intimate 18 knowledge of landscapes across seasons (Brattland and Mustonen, 2018), changing landscapes resulting in 19 solastalgia and ecological grief (Cunsolo and Ellis, 2018), and some Indigenous practices and cultural assets, 20 such as burial grounds, nomadic camp sites, graveyards, seasonal dwellings, and routes and pathways 21 causing disruptions to mind and memory (Mustonen and Mustonen, 2016). Recognizing these intangible 22 losses and damages is critical for understanding how to achieve climate resilience in the Arctic (Tschakert et 23 al., 2019; Sawatzky et al., 2020). | Heritage | 3590 - 3590 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 48 49 The net outcome of the population dynamics processes of growth, mortality and regeneration is change in 50 species composition as a consequence of a changing climate. In the Amazon forests, dry habitat-affiliated 51 genera have become more abundant among the newly recruited trees, while the mortality of moist habitat- 52 affiliated genera has increased at places where the dry season has intensified most, thus driving a slow shift 53 towards a drier forest type (Esquivel-Muelbert et al. 2019). A similar multi-decadal shift in West-African 54 forest species composition towards more dry-affiliated species as a response to long-term drying has been 55 recorded (Aguirre-Gutiérrez et al. 2020). While upward shifts in the tree line and in the range of individual 56 tree species have been recorded at several temperate mountain regions, evidence from the tropics is rare. A 57 large-scale study from 200 plot inventories of >2000 tree species across a ~3000m elevation gradient in the ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>FINAL DRAFT Cross-Chapter Paper 7 IPCC WGII Sixth Assessment Report Do Not Cite, Quote or Distribute CCP7-12 Total pages: 63 1 Andean tropics and sub-tropics has shown that the relative abundances of tree species from lower, warmer 2 locations were increasing at these sites indicating that “thermophilization of vegetation” (increased 3 domination of plant species from warmer locations) was indeed taking place as expected (Fadrique et al. | Heritage | 3624 - 3625 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 5 6 For the Amazon, deforestation (ca. 40% of the region) in combination with climate change will raise the 7 prospect of passing a tipping point leading to large-scale savannization of the rainforest biome, but but uncertain remains that this will take place in the 21st 8 century (Nobre et al. 2016; Jia et al. 2019; Douville et 9 al. 2021). However, considering that the Amazon has already lost ca. 20% of its forests (Nobre et al. 2016), 10 crossing the tipping point may not only create savannas of the deforested parts but may also result in 11 precipitation reductions of 40% in non-deforested parts of the western Amazon due to a breakdown of the 12 South American monsoonal circulation and the subsequent western cascade of precipitation and 13 evapotranspiration (Boers et al. 2017). Other effects of forest degradation include loss of ecosystem services, 14 biodiversity, carbon storage, and indigenous culture (Watson et al. 2018; Strassburg et al. 2019; Gatti et al. | Heritage | 3628 - 3628 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 30 31 32 [START BOX CCP7.1 HERE] 33 34 Box CCP7.1: Indigenous Knowledge and Local Knowledge and Community-Based Adaptation 35 36 Purely scientific knowledge, albeit indispensable, is insufficient to address climate change. Indigenous 37 Knowledge systems, embedded in social and cultural structures, are integral to climate resilience and 38 adaptation (high confidence) (Ajani 2013; Tengö et al. 2014; Hiwasaki et al. 2015; Roue and Nakashima 39 2018)[AR5 WG2 12.3.3, 14.3.1, 20.4.2 , SRCCL 4.8.1, 4.8.2, SR15 4.3.5]. Indigenous knowledge and local 40 knowledge (IK and LK) and community-based adaptation (CbA) have received increasing recognition across 41 all sectors (high confidence) (Reid and Huq 2014; Wright et al. 2014; MOSTE 2015)[SRCCL 4.1.6, 5.3.5, 42 SR15 Box 4.3] (Figure Box CCP7.1.1). Forest Indigenous knowledge is closely linked to traditional land-use 43 practices and local governance (Roberts et al. 2009); it is embodied in art, rituals, food, agriculture and 44 customary laws, among others (Hiwasaki et al. 2015; Camico et al. 2021). CbA is a community led process 45 based on its desires, priorities, knowledge and capacities; which empowers people as central players in 46 climate change adaptation (Reid et al. 2009) [SRCCL 5.3.5]. | Heritage | 3629 - 3629 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 52 53 Role of IK and LK and CbA for Climate Change Adaptation in Tropical Forests 54 55 Local forest and Indigenous forest management systems have developed over long time periods; generating 56 social practices and institutions that have supported livelihoods and cultures for generations (high 57 confidence) (Seppälä 2009; Martin et al. 2010; Parrotta and Agnoletti 2012; Camico et al. 2021). | Heritage | 3629 - 3629 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 12 13 Integration of IK and LK Systems, CbA and Modern Scientific Systems 14 15 Several authors have highlighted the need to foster a respectful a dialogue between IK and LK and modern 16 science towards a holistic research model (high confidence) (Berkes 2010; Ajani 2013; Tengö et al. 2014; 17 Roue and Nakashima 2018)[AR5 WG2 12.3.3, 14.2.2]; but few ecological studies have attempted this 18 integration (Keenan 2015; Vadigi 2016). Examples in tropical forest ecosystems include topics such as 19 monitoring climate impacts; local climates; seed, water and land management resilience-increasing practices 20 and climate threats to traditional agriculture (Parrotta and Agnoletti 2012; Fernández-Llamazares et al. 2017; 21 Camico et al. 2021; Panduro Meléndez et al. 2021). A growing number of methods are available to help this 22 dialogue [SRCCL 7.5.1] (Reid et al. 2009; Tengö et al. 2014; Tengö et al. 2017; Roue and Nakashima 23 2018)(Figure Box CCP7.1.1). While there is expanding interest among decision-makers, researchers, 24 Indigenous Peoples and civil society on IK and LK (Hiwasaki et al. 2015; Maillet and Ford 2016), gaps 25 remain regarding links between place-and-culture dimensions and adaptive capacities (Ford et al. 2016). | Heritage | 3630 - 3630 |

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| IPCC | IPCC_AR6_WGII_Full_ Report | (Lee 2017) 5 Gender Equality Within genders, other characteristics such as class, race, caste, culture, wealth, age and ethnicity influence responses and affect the impact of climate variability and change on livelihoods Despite challenges, Nepal's community forestry policy is considered one of the most progressive, as it allows women to exercise equal rights with men in the management and utilization of community forests. Furthermore, women-only forestry groups have registered many success stories. | Heritage | 3644 - 3644 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 25 The forests provide many kinds of economic products, such as timber, medicines, and food, recreational 26 services, such as nature trekking, bird and wildlife watching, to mention a few. Indigenous People and other 27 forest-dependent communities have shown extraordinary knowledge on how to manage forest resources to 28 meet their subsistence needs without causing forest degradation. This forest culture and wisdom are broken 29 when the rate of forest extraction changes into unplanned and unsustainable large-scale transformation. | Heritage | 3652 - 3652 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 30 31 Deforestation and land-use changes in tropical forests cause not only physical and biological changes on flora 32 and fauna but also rapid changes in cultures harming forest peoples. A degraded tropical forest is prone and 33 more vulnerable to climate change. An increase in temperature in lowlands creates an unfavorable condition 34 for optimum growths of many kinds of plant species, which affects, as well, several agricultural plants. Coffee 35 farmers, for example, are forced to open new forest frontiers in highland areas to meet an optimum temperature 36 for the growth of coffee. | Heritage | 3652 - 3652 |
| IPCC | IPCC_AR6_WGII_Full_ Report | 10 11 To protect tropical forests a collective action of all nations is needed. It requires a global effort to stop 12 deforestation and the conversion of tropical forests. The role of Indigenous Peoples and local communities as 13 forest keepers must be strengthened. Economic incentives for protecting tropical forests, among other 14 strategies, could facilitate collective actions towards a sustainable management of tropical forests. Sustainable, 15 effective and just strategies to increase the resilience of tropical forests need to consider the complex political, 16 social and economic dynamics involved, including the goals, identity and livelihood priorities of Indigenous 17 Peoples and local communities beyond natural resource management. Strategies can benefit from integrating 18 knowledge and know-how from traditional cultures, fostering transitions towards more sustainable systems. | Heritage | 3653 - 3653 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | APPROVED Summary for Policymakers IPCC AR6 WG III Subject to copyedit SPM-37 Total pages: 63 has been projected to be around 1–4 trillion dollars from 2015 to 2050 to limit global warming to approximately 2ºC, and it will be higher if global warming is limited to approximately 1.5ºC (medium confidence). In this context, coal assets are projected to be at risk of being stranded before 2030, while oil and gas assets are projected to be more at risk of being stranded toward mid-century. A low-emission energy sector transition is projected to reduce international trade in fossil fuels. (high confidence) {6.7, Figure 6.35} C.4.5 Global methane emissions from energy supply, primarily fugitive emissions from production and transport of fossil fuels, accounted for about 18% [13%-23%] of global GHG emissions from energy supply, 32% [22%-42%] of global methane emissions, and 6% [4%-8%] of global GHG emissions in 2019 (high confidence). About 50–80% of CH4 emissions from these fossil fuels could be avoided with currently available technologies at less than USD50 tCO2-eq-1 (medium confidence). {6.3, 6.4.2, Box 6.5, 11.3, 2.2.2, Table 2.1, Figure 2.5; Annex1 Glossary} C.4.6 CCS is an option to reduce emissions from large-scale fossil-based energy and industry sources, provided geological storage is available. When CO2 is captured directly from the atmosphere (DACCS), or from biomass (BECCS), CCS provides the storage component of these CDR methods. CO2 capture and subsurface injection is a mature technology for gas processing and enhanced oil recovery. In contrast to the oil and gas sector, CCS is less mature in the power sector, as well as in cement and chemicals production, where it is a critical mitigation option. The technical geological CO2 storage capacity is estimated to be on the order of 1000 gigatonnes of CO2, which is more than the CO2 storage requirements through 2100 to limit global warming to 1.5°C, although the regional availability of geological storage could be a limiting factor. If the geological storage site is appropriately selected and managed, it is estimated that the CO2 can be permanently isolated from the atmosphere. Implementation of CCS currently faces technological, economic, institutional, ecological-environmental and socio�cultural barriers. Currently, global rates of CCS deployment are far below those in modelled pathways limiting global warming to 1.5°C or 2°C. Enabling conditions such as policy instruments, greater public support and technological innovation could reduce these barriers. (high confidence) {2.5, 6.3, 6.4, 6.7, 11.3, 11.4, Cross-Chapter Box 8 in Chapter 12, Figure TS.31, SRCCS Chapter 5} APPROVED Summary for Policymakers IPCC AR6 WG III Subject to copyedit SPM-38 Total pages: 63 C.5 Net-zero CO2 emissions from the industrial sector are challenging but possible. Reducing industry emissions will entail coordinated action throughout value chains to promote all mitigation options, including demand management, energy and materials efficiency, circular material flows, as well as abatement technologies and transformational changes in production processes. Progressing towards net zero GHG emissions from industry will be enabled by the adoption of new production processes using low and zero GHG electricity, hydrogen, fuels, and carbon management. (high confidence) {11.2, 11.3, 11.4, Box TS.4} C.5.1 The use of steel, cement, plastics, and other materials is increasing globally, and in most regions. There are many sustainable options for demand management, materials efficiency, and circular material flows that can contribute to reduced emissions, but how these can be applied will vary across regions and different materials. These options have a potential for being more used in industrial practice and would need more attention from industrial policy. These options, as well as new production technologies, are generally not considered in recent global scenarios nor in national economy-wide scenarios due to relative newness. As a consequence, the mitigation potential in some scenarios is underestimated compared to bottom-up industry-specific models. (high confidence) {3.4, 5.3, Figure 5.7, 11.2, Box 11.2, 11.3, 11.4, 11.5.2, 11.6} C.5.2 For almost all basic materials – primary metals [FOOTNOTE 56], building materials and chemicals – many low- to zero- GHG intensity production processes are at the pilot to near-commercial and in some cases commercial stage but not yet established industrial practice. Introducing new sustainable basic materials production processes could increase production costs but, given the small fraction of consumer cost based on materials, are expected to translate into minimal cost increases for final consumers. Hydrogen direct reduction for primary steelmaking is near-commercial in some regions. Until new chemistries are mastered, deep reduction of cement | Heritage | 37 - 39 |

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| IPCC | IPCC_AR6_WGIII_Full_ Report | and water security, wood supply, livelihoods and land tenure and land-use rights of Indigenous Peoples, local communities and small land owners. Many options have co-benefits but those that compete for land and land-based resources can pose risks. The scale of benefit or risk largely depends on the type of activity undertaken, deployment strategy (e.g., scale, method), and context (e.g., soil, biome, climate, food system, land ownership) that vary geographically and over time. Risks can be avoided when AFOLU mitigation is pursued in response to the needs and perspectives of multiple stakeholders to achieve outcomes that maximize co-benefits while limiting trade-offs. (high confidence) {7.4, 7.6, 12.3}<br>APPROVED Summary for Policymakers IPCC AR6 WG III Subject to copyedit SPM-44 Total pages: 63 C.9.3 Realising the AFOLU potential entails overcoming institutional, economic and policy constraints and managing potential trade-offs (high confidence). Land-use decisions are often spread across a wide range of landowners; demand-side measures depend on billions of consumers in diverse contexts. Barriers to the implementation of AFOLU mitigation include insufficient institutional and financial support, uncertainty over long-term additionality and trade-offs, weak governance, insecure land ownership, the low incomes and the lack of access to alternative sources of income, and the risk of reversal. Limited access to technology, data, and know-how is a barrier to implementation. Research and development are key for all measures. For example, measures for the mitigation of agricultural CH4 and N2O emissions with emerging technologies show promising results. However the mitigation of agricultural CH4 and N2O emissions is still constrained by cost, the diversity and complexity of agricultural systems, and by increasing demands to raise agricultural yields, and increasing demand for livestock products. (high confidence) {7.4, 7.6} C.9.4 Net costs of delivering 5-6 Gt CO2 yr-1 of forest related carbon sequestration and emission reduction as assessed with sectoral models are estimated to reach to ~USD400 billion yr-1 by 2050. The costs of other AFOLU mitigation measures are highly context specific. Financing needs in AFOLU, and in particular in forestry, include both the direct effects of any changes in activities as well as the opportunity costs associated with land use change. Enhanced monitoring, reporting and verification capacity and the rule of law are crucial for land-based mitigation, in combination with policies also recognising interactions with wider ecosystem services, could enable engagement by a wider array of actors, including private businesses, NGOs, and Indigenous Peoples and local communities. (medium confidence) {7.6, 7.7}<br>C.9.5 Context specific policies and measures have been effective in demonstrating the delivery of AFOLU carbon sequestration and GHG emission reduction options but the above-mentioned constraints hinder large scale implementation (medium confidence). Deploying land-based mitigation can draw on lessons from experience with regulations, policies, economic incentives, payments (e.g., for biofuels, control of nutrient pollution, water regulations, conservation and forest carbon, ecosystem services, and rural livelihoods), and from diverse forms of knowledge such as Indigenous knowledge, local knowledge and scientific knowledge. Indigenous Peoples, private forest owners, local farmers and communities manage a significant share of global forests and agricultural land and play a central role in land-based mitigation options. Scaling successful policies and measures relies on governance that emphasises integrated land use planning and management framed by SDGs, with support for implementation. (high confidence) {7.4, Box 7.2, 7.6} C.10 Demand-side mitigation encompasses changes in infrastructure use, end-use technology adoption, and socio-cultural and behavioural change. Demand-side measures and new ways of end-use service provision can reduce global GHG emissions in end use sectors by 40-70% by 2050 compared to baseline scenarios, while some regions and socioeconomic groups require additional energy and resources. Demand side mitigation response options are consistent with improving basic wellbeing for all. (high confidence) (Figure SPM.6) {5.3, 5.4, Figure 5.6, Figure 5.14, 8.2, 9.4, 10.2, 11.3, 11.4, 12.4, Figure TS.22} C.10.1 Infrastructure design and access, and technology access and adoption, including information and communication technologies, influence patterns of demand and ways of providing services, such as mobility, shelter, water, sanitation, and nutrition. Illustrative global low demand scenarios, accounting for regional differences, indicate that more efficient end-use energy conversion can improve | Heritage | 44 - 46 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | FOOTNOTE 64: Status consumption refers to the consumption of goods and services which publicly demonstrates social prestige.<br>APPROVED Summary for Policymakers IPCC AR6 WG III Subject to copyedit SPM-46 Total pages: 63 Figure SPM.6 Indicative potential of demand-side mitigation options by 2050 Figure SPM.6 covers the indicative potential of demand-side options for the year 2050. Figure SPM.7 covers cost and potentials for the year 2030. Demand-side mitigation response options are categorised into three broad domains: 'socio-cultural factors', associated with individual choices, behaviour; and lifestyle changes, social norms and culture; 'infrastructure use', related to the design and use of supporting hard and soft infrastructure that enables changes in individual choices and behaviour; and 'end-use technology adoption', refers to the uptake of technologies by end-users. Demand side mitigation is a central element of the IMP-LD and IMP-SP scenarios (Figure SPM.5). | Heritage | 46 - 47 |

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| IPCC | IPCC_AR6_WGIII_Full_ Report | confidence) {3.4, 7.4, 12.3, Cross-Chapter Box 8 in Chapter 12} C.11.1 CDR refers to anthropogenic activities that remove $CO_2$ from the atmosphere and store it durably in geological, terrestrial, or ocean reservoirs, or in products. CDR methods vary in terms of their maturity, removal process, timescale of carbon storage, storage medium, mitigation potential, cost, co-benefits, impacts and risks, and governance requirements (high confidence). Specifically, maturity ranges from lower maturity (e.g., ocean alkalinisation) to higher maturity (e.g., reforestation); removal and storage potential ranges from lower potential (<1 Gt $CO_2$ yr -1 , e.g., blue carbon management) to higher potential (>3 Gt $CO_2$ yr-1 , e.g., agroforestry); costs range from lower cost (e.g., 45-100 USD/t$CO_2$ for soil carbon sequestration) to higher cost (e.g., 100-300 USD/t$CO_2$ for DACCS) (medium confidence). Estimated storage timescales vary from decades to centuries for methods that store carbon in vegetation and through soil carbon management, to ten thousand years or more for methods that store carbon in geological formations (high confidence). The processes by which $CO_2$ is removed from the atmosphere are categorised as biological, geochemical or chemical. Afforestation, reforestation, improved forest management, agroforestry and soil carbon sequestration are currently the only widely practiced CDR methods (high confidence). {7.4, 7.6, 12.3, Table 12.6, Table TS.7, Cross-Chapter Box 8 in Chapter 12, WG I 5.6} C.11.2 The impacts, risks and co-benefits of CDR deployment for ecosystems, biodiversity and people will be highly variable depending on the method, site-specific context, implementation and scale (high confidence). Reforestation, improved forest management, soil carbon sequestration, peatland restoration and blue carbon management are examples of methods that can enhance biodiversity and ecosystem functions, employment and local livelihoods, depending on context (high confidence). In contrast, afforestation or production of biomass crops for BECCS or biochar, when poorly implemented, can have adverse socio-economic and environmental impacts, including on biodiversity, food and water security, local livelihoods and on the rights of Indigenous Peoples, especially if implemented at large scales and where land tenure is insecure (high confidence). Ocean fertilisation, if implemented, could<br>APPROVED Summary for Policymakers IPCC AR6 WG III Subject to copyedit SPM-48 Total pages: 63 lead to nutrient redistribution, restructuring of ecosystems, enhanced oxygen consumption and acidification in deeper waters (medium confidence). {7.4, 7.6, 12.3, 12.5} C.11.3 The removal and storage of $CO_2$ through vegetation and soil management can be reversed by human or natural disturbances; it is also prone to climate change impacts. In comparison, $CO_2$ stored in geological and ocean reservoirs (via BECCS, DACCS, ocean alkalinisation) and as carbon in biochar is less prone to reversal. (high confidence) {6.4, 7.4, 12.3} C11.4 In addition to deep, rapid, and sustained emission reductions CDR can fulfil three different complementary roles globally or at country level: lowering net $CO_2$ or net GHG emissions in the near�term; counterbalancing 'hard-to-abate' residual emissions (e.g., emissions from agriculture, aviation, shipping, industrial processes) in order to help reach net zero $CO_2$ or net zero GHG emissions in the mid-term; achieving net negative $CO_2$ or GHG emissions in the long-term if deployed at levels exceeding annual residual emissions (high confidence) {3.3, 7.4, 11.3, 12.3, Cross-Chapter Box 8 in Chapter 12} C.11.5 Rapid emission reductions in all sectors interact with future scale of deployment of CDR methods, and their associated risks, impacts and co-benefits. Upscaling the deployment of CDR methods depends on developing effective approaches to address sustainability and feasibility constraints, potential impacts, co-benefits and risks. Enablers of CDR include accelerated research, development and demonstration, improved tools for risk assessment and management, targeted incentives and development of agreed methods for measurement, reporting and verification of carbon flows. (high confidence) {3.4, 7.6, 12.3} C.12 Mitigation options costing USD100 t$CO_2$-eq-1 or less could reduce global GHG emissions by at least half the 2019 level by 2030 (high confidence). Global GDP continues to grow in modelled pathways [FOOTNOTE 65] but, without accounting for the economic benefits of mitigation action from avoided damages from climate change nor from reduced adaptation costs, it is a few percent lower in 2050 compared to pathways without mitigation beyond current policies. The global economic benefit of | Heritage | 48 - 49 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | E.1.1 Several mitigation options, notably solar energy, wind energy, electrification of urban systems, urban green infrastructure, energy efficiency, demand side management, improved forest- and crop/grassland management, and reduced food waste and loss, are technically viable, are becoming increasingly cost effective, and are generally supported by the public. This enables deployment in many regions. (high confidence) While many mitigation options have environmental co-benefits, including improved air quality and reducing toxic waste, many also have adverse environmental impacts, such as reduced biodiversity, when applied at very large scale, for example very large scale bioenergy or large scale use of battery storage, that would have to be managed (medium confidence). Almost all mitigation options face institutional barriers that need to be addressed to enable their application at scale (medium confidence). {6.4, Figure 6.19, 7.4, 8.5, Figure 8.19, 9.9, Figure 9.20, 10.8, Figure 10.23, 12.3, Figure 12.4, Figure TS.31} E.1.2 The feasibility of mitigation options varies according to context and time. For example, the institutional capacity to support deployment varies across countries; the feasibility of options that involve large-scale land use changes varies across regions; spatial planning has a higher potential at early stages of urban development; the potential of geothermal is site specific; and capacities, cultural and local conditions can either inhibit or enable demand-side responses. The deployment of solar and wind energy has been assessed to become increasingly feasible over time. The feasibility of some options can increase when combined or integrated, such as using land for both agriculture and<br>APPROVED Summary for Policymakers IPCC AR6 WG III Subject to copyedit SPM-58 Total pages: 63 centralised solar production. (high confidence) {6.4, 6.6, 7.4, 8.5, 9.9, 10.8, 12.3, Appendix 10.3, Table SM6, Table SM8.2, Table SM9.1, Table SM12.B} E.1.3 Feasibility depends on the scale and speed of implementation. Most options face barriers when they are implemented rapidly at a large scale, but the scale at which barriers manifest themselves varies. | Heritage | 58 - 59 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | 6 The ease of switching to electricity means that hydrogen is not expected to be a dominant pathway for 7 buildings {Box 9.6}. Using electricity directly for heating, cooling and other building energy demand 8 is more efficient than using hydrogen as a fuel, for example, in boilers or fuel cells. In addition, 9 electricity distribution is already well developed in many regions compared to essentially non-existent 10 hydrogen infrastructure, except for a few chemicals industry pipelines. At the same time, hydrogen 11 could potentially be used for on-site storage should technology advance sufficiently. | Heritage | 120 - 120 |

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| IPCC | IPCC_AR6_WGIII_Full_ Report | confidence). This growth is projected to 27 take place across all transport modes. Increases in demand notwithstanding, scenarios that limit 28 warming to 1.5°C degree with no or limited overshoot suggest that a 59% reduction (42-68% 29 interquartile range) in transport-related CO2 emissions by 2050, compared to modelled 2020 levels is 30 required. While many global scenarios place greater reliance on emissions reduction in sectors other 31 than transport, a quarter of the 1.5°C scenarios describe transport-related CO2 emissions reductions in 32 excess of 68% (relative to modelled 2020 levels) (medium confidence). Illustrative Mitigation Pathways 33 IMP-ren and IMP-LD (TS 4.2) describe emission reductions of 80% and 90% in the transport sector, 34 respectively, by 2050. Transport-related emission reductions, however, may not happen uniformly 35 across regions. For example, transport emissions from the Developed Countries, and Eastern Europe 36 and West-Central Asia countries decrease from 2020 levels by 2050 across all scenarios limiting global 37 warming to 1.5°C by 2100, but could increase in Africa, Asia and developing Pacific (APC), Latin 38 America and Caribbean, and the Middle East in some of these scenarios. {10.7} 39 The scenarios literature indicates that fuel and technology shifts are crucial in reducing carbon 40 emissions to meet temperature goals (high confidence). In general terms, electrification tends to play 41 the key role in land-based transport, but biofuels and hydrogen (and derivatives) could play a role in 42 decarbonisation of freight in some contexts. Biofuels and hydrogen (and derivatives) are expected to be 43 more prominent in shipping and aviation. The shifts towards these alternative fuels must occur 44 alongside shifts towards clean technologies in other sectors. {10.7} 45 There is a growing awareness of the need to plan for the significant expansion of low-carbon 46 energy infrastructure, including low-carbon power generation and hydrogen production, to 47 support emissions reductions in the transport sector (high confidence). Integrated energy planning ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Technical Summary IPCC AR6 WG III Do Not Cite, Quote or Distribute TS-69 Total pages: 142 1 and operations that take into account energy demand and system constraints across all sectors (transport, 2 buildings, and industry) offer the opportunity to leverage sectoral synergies and avoid inefficient 3 allocation of energy resources. Integrated planning of transport and power infrastructure would be 4 particularly useful in developing countries where 'greenfield' development doesn't suffer from 5 constraints imposed by legacy systems. {10.3, 10.4, 10.8} 6 The deployment of low-carbon aviation and shipping fuels that support decarbonisation of the 7 transport sector could require changes to national and international governance structures 8 (medium confidence). The UNFCCC does not specifically cover emissions from international shipping 9 and aviation. Reporting emissions from international transport is at the discretion of each country. While 10 the International Civil Aviation Organisation (ICAO) and International Maritime Organisation (IMO) 11 have established emissions reductions targets, only strategies to improve fuel efficiency and demand 12 reductions have been pursued, and there has been minimal commitment to new technologies. {10.5, 13 10.6, 10.7} 14 There are growing concerns about resource availability, labour rights, non-climate 15 environmental impacts, and costs of critical minerals needed for lithium-ion batteries (medium 16 confidence). Emerging national strategies on critical minerals and the requirements from major vehicle 17 manufacturers are leading to new, more geographically diverse mines. The standardisation of battery 18 modules and packaging within and across vehicle platforms, as well as increased focus on design for 19 recyclability are important. Given the high degree of potential recyclability of lithium-ion batteries, a 20 nearly closed-loop system in the future could mitigate concerns about critical mineral issues (medium 21 confidence). {10.3, 10.8} 22 Legislated climate strategies are emerging at all levels of government, and together with pledges 23 for personal choices, could spur the deployment of demand and supply-side transport mitigation 24 strategies (medium confidence). At the local level, legislation can support local transport plans that 25 include commitments or pledges from local institutions to encourage behaviour change by adopting an 26 organisational culture that motivates sustainable behaviour with inputs from the creative arts. Such 27 institution-led mechanisms could include bike-to-work campaigns, free transport passes, parking 28 charges, or eliminating car benefits. Community- | Heritage | 132 - 135 |

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| IPCC | IPCC_AR6_WGIII_Full_Report | No data. {12.3.1}  1 Range based on authors' estimates (as assessed from literature) are shown, with full literature ranges shown in brackets  ACCEPTED VERSION   SUBJECT TO FINAL EDITS<br>Final Government Distribution Technical Summary IPCC AR6 WG III  Do Not Cite, Quote or Distribute TS-98 Total pages: 142  1 TS. 5.8 Demand-side aspects of mitigation  2 The assessment of the social science literature and regional case studies reveals how social norms,   3 culture, and individual choices interact with infrastructure and other structural changes over time. This   4 provides new insight into climate change mitigation strategies, and how economic and social activity   5 might be organised across sectors to support emission reductions. To enhance well-being, people   6 demand services and not primary energy and physical resources per se. Focusing on demand for services   7 and the different social and political roles people play broadens the participation in climate action. (Box   8 TS.11)  9 Demand-side mitigation and new ways of providing services can help Avoid and Shift final service   10 demands and Improve service delivery. Rapid and deep changes in demand make it easier for   11 every sector to reduce GHG emissions in the short and medium term (high confidence). {5.2, 5.3}  12 The indicative potential of demand-side strategies across all sectors to reduce emissions is 40-70%   13 by 2050 (high confidence). Technical mitigation potentials compared to the International Energy   14 Agency's 2020 World Energy Outlook STEPS (Stated Policy Scenarios) baseline are up to 5.7 GtCO2-eq for   15 building use and construction, 8 GtCO2-eq for food demand, 6.5 GtCO2-eq for land transport, and 5.2   16 GtCO2-eq for industry. Mitigation strategies can be classified as Avoid-Shift-Improve (ASI) options,   17 that reflect opportunities for socio-cultural, infrastructural, and technological change. The greatest   18 Avoid potential comes from reducing long-haul aviation and providing short-distance low-carbon urban   19 infrastructures. The greatest Shift potential would come from switching to plant-based diets. The   20 greatest Improve potential comes from within the building sector, and in particular increased use of   21 energy efficient end-use technologies and passive housing. (Figure TS.20, Figure TS.21) {5.3.1, 5.3.2,   22 Figure 5.7, Figure 5.8, Table 5.1, Table SM 5.2}  23 Socio-cultural and lifestyle changes can accelerate climate change mitigation (medium   24 confidence). Among 60 identified actions that could change individual consumption, individual   25 mobility choices have the largest potential to reduce carbon footprints. Prioritising car-free mobility by   walking and cycling and adoption of electric mobility could save 2 tCO2-eq cap-1 yr-1 26 . Other options   27 with high mitigation potential include reducing air travel, cooling setpoint adjustments, reduced   28 appliance use, shifts to public transit, and shifting consumption towards plant-based diets. {5.3.1,   29 5.3.1.2, Figure 5.8}  30  31 START BOX TS.11 HERE  32 Box TS.11: A New Chapter in WG III AR6 Focusing on the Social Science of Demand, and   33 Social Aspects of Mitigation  34 The WG III contribution to the Sixth Assessment Report of the IPCC (AR6) features a distinct chapter   35 on demand, services and social aspects of mitigation {5}. The scope, theories, and evidence for such an   36 assessment are addressed in Sections 5.1 and 5.4 within Chapter 5 and a Social Science Primer as an   37 Appendix to Chapter 5. | Heritage | 161 - 162 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 6 A social science perspective is important in two ways. By adding new actors and perspectives, it (i)   7 provides more options for climate mitigation; and (ii) helps to identify and address important social and   8 cultural barriers and opportunities to socioeconomic, technological, and institutional change. Demand-  9 side mitigation involves five sets of social actors: individuals (e.g., consumption choices, habits),   10 groups and collectives (e.g., social movements, values), corporate actors (e.g., investments,   11 advertising), institutions (e.g., political agency, regulations), and infrastructure actors (e.g., very long-  12 term investments and financing). Actors either contribute to the status-quo of a global high-carbon,   13 consumption, and GDP growth-oriented economy, or help generate the desired change to a low-carbon   14 energy-services, well-being, and equity-oriented economy. Each set of actors has novel implications for   15 the design and implementation of both demand- and supply-side mitigation policies. They show   16 important synergies, making energy demand mitigation a dynamic problem where the packaging and/or  17 sequencing of different policies play a role in their effectiveness {5.5, 5.6}. Incremental interventions   18 change social practices, simultaneously affecting emissions and well-being. The transformative change   19 requires coordinated action across all five sets of actors (Table 5.4), using social science insights about   20 intersection of behaviour, culture, institutional and infrastructural changes for policy design and   21 implementation. Avoid, Shift, and Improve choices by individuals, households and communities support   22 mitigation {5.3.1.1, Table 5.1}. They are instigated by role models, changing social norms driven by   23 policies and social movements. They also require appropriate infrastructures designed by urban   24 planners and building and transport professionals, corresponding investments, and a political culture   25 supportive of demand side mitigation action. | Heritage | 163 - 163 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 26 END BOX TS.11 HERE  27  28 Leveraging improvements in end-use service delivery through behavioural and technological   29 innovations, and innovations in market organisation, leads to large reductions in upstream   30 resource use (high confidence). Analysis of indicative potentials range from a factor 10- to 20-fold   31 improvement in the case of available energy (exergy) analysis, with the highest improvement potentials   32 at the end-user and service-provisioning levels. Realisable service level efficiency improvements could   33 reduce upstream energy demand by 45% in 2050. (Figure TS.20) {5.3.2, Figure 5.10}  ACCEPTED VERSION   SUBJECT TO FINAL EDITS<br>Final Government Distribution Technical Summary IPCC AR6 WG III  Do Not Cite, Quote or Distribute TS-100 Total pages: 142  1  2 Figure TS.20: Demand-side strategies for mitigation. Demand-side mitigation is about more than   3 behavioural change and transformation happens through societal, technological and institutional changes  4 {Figure 5.10, Figure 5.14}  5  6  ACCEPTED VERSION   SUBJECT TO FINAL EDITS<br>Final Government Distribution Technical Summary IPCC AR6 WG III  Do Not Cite, Quote or Distribute TS-101 Total pages: 142  1  2 Figure TS.21: Demand-side mitigation can be achieved through changes in socio-cultural factors,   3 infrastructure design and use, and technology adoption  4 Figure TS.21 legend: Mitigation response options related to demand for services have been categorised into   5 three domains: 'socio-cultural factors', related to social norms, culture, and individual choices and behaviour;   6 'infrastructure use', related to the provision and use of supporting infrastructure that enables individual choices   7 and behaviour; and 'technology adoption', which refers to the uptake of technologies by end users. | Heritage | 163 - 165 |

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| IPCC | IPCC_AR6_WGIII_Full_ Report | 10 There are knowledge gaps for assessing CE opportunities within mitigation models due to CE's many 11 cross-sectoral linkages and data gaps related to its nascent state {3.4.4}. Opportunity exists to bridge 12 knowledge from the Industrial Ecology field, which has historically studied CE, to the mitigation 13 modelling community for improved analysis of interventions and policies for AR7. For instance, a 14 global CE knowledge sharing platform is helpful for CE performance measurement, reporting and 15 accounting. {5.3, 9.5, 11.7} 16 END BOX TS.12 HERE 17 18 Providing better services with less energy and resource input has high technical potential and is 19 consistent with providing well-being for all (medium confidence). The assessment of 19 demand- 20 side mitigation options and 18 different constituents of well-being showed that positive impacts on well- 21 being outweigh negative ones by a factor of 11. {5.2, 5.2.3, Figure 5.6} 22 Demand-side mitigation options bring multiple interacting benefits (high confidence). Energy 23 services to meet human needs for nutrition, shelter, health, etc. are met in many different ways with 24 different emissions implications that depend on local contexts, cultures, geography, available 25 technologies, and social preferences. In the near term, many less-developed countries, and poor people 26 everywhere, require better access to safe and low-emissions energy sources to ensure decent living 27 standards and increase energy savings from service improvements by about 20-25%. (Figure TS.22) 28 {5.2, 5.4.5, Figure 5.3, Figure 5.4, Figure 5.5, Figure 5.6, Box 5.2, Box 5.3} 29 Granular technologies and decentralized energy end-use, characterised by modularity, small unit 30 sizes and small unit costs, diffuse faster into markets and are associated with faster technological 31 learning benefits, greater efficiency, more opportunities to escape technological lock-in, and 32 greater employment (high confidence). Examples include solar PV systems, batteries, and thermal 33 heat pumps. {5.3, 5.5, 5.5.3} 34 Wealthy individuals contribute disproportionately to higher emissions and have a high potential 35 for emissions reductions while maintaining decent living standards and well-being (high 36 confidence). Individuals with high socio-economic status are capable of reducing their GHG emissions 37 by becoming role models of low-carbon lifestyles, investing in low-carbon businesses, and advocating 38 for stringent climate policies. {5.4.1, 5.4.3, 5.4.4, Figure 5.14} 39 Demand-side solutions require both motivation and capacity for change (high confidence).<br><br>removal. {14.2, 14.3, 14.4, 14.5, 14.6, Cross- 33 Working Group Box 4 in Chapter 14} 34 35 TS. 6.3 Societal aspects of mitigation 36 Social equity reinforces capacity and motivation for mitigating climate change (medium 37 confidence). Impartial governance such as fair treatment by law-and-order institutions, fair treatment 38 by gender, and income equity, increases social trust, thus enabling demand-side climate policies. High 39 status (often high carbon) item consumption may be reduced by taxing absolute wealth without 40 compromising well-being. {5.2, 5.4.2, 5.6} 41 42 Policies that increase the political access and participation of women, racialised, and marginalised 43 groups, increase the democratic impetus for climate action (high confidence). Including more 44 differently situated knowledge and diverse perspectives makes climate mitigation policies more 45 effective. {5.2, 5.6} 46 ACCEPTED VERSION SUBJECT TO FINAL EDITS | Heritage | 167 - 167 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | Final Government Distribution Technical Summary IPCC AR6 WG III Do Not Cite, Quote or Distribute TS-121 Total pages: 142 1 Greater contextualisation and granularity in policy approaches better addresses the challenges 2 of rapid transitions towards zero-carbon systems (high confidence). Larger systems take more time 3 to evolve, grow, and change compared to smaller ones. Creating and scaling up entirely new systems 4 takes longer than replacing existing technologies and practices. Late adopters tend to adopt faster than 5 early pioneers. Obstacles and feasibility barriers are high in the early transition phases. Barriers decrease 6 as a result of technical and social learning processes, network building, scale economies, cultural 7 debates, and institutional adjustments. {5.5, 5.6} 8 9 Mitigation policies that integrate and communicate with the values people hold are more 10 successful (high confidence). Values differ between cultures. Measures that support autonomy, energy 11 security and safety, equity and environmental protection, and fairness resonate well in many 12 communities and social groups. Changing from a commercialised, individualised, entrepreneurial 13 training model to an education cognizant of planetary health and human well-being can accelerate 14 climate change awareness and action. {5.4.1, 5.4.2} 15 16 Changes in consumption choices that are supported by structural changes and political action 17 enable the uptake of low-carbon choices (high confidence). Policy instruments applied in 18 coordination can help to accelerate change in a consistent desired direction. Targeted technological 19 change, regulation, and public policy can help in steering digitalisation, the sharing economy, and 20 circular economy towards climate change mitigation. (Box TS.12, Box TS.14) {5.3, 5.6} 21 22 Complementarity in policies helps in the design of an optimal demand-side policy mix (medium 23 confidence). In the case of energy efficiency, for example, this may involve CO2 pricing, standards and 24 norms, and information feedback. {5.3, 5.4, 5.6} 25 26 27 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Technical Summary IPCC AR6 WG III Do Not Cite, Quote or Distribute TS-122 Total pages: 142 1 TS. 6.4 Investment and finance 2 Finance to reduce net GHG emissions and enhance resilience to climate impacts is a critical 3 enabling factor for the low carbon transition. Fundamental inequities in access to finance as well 4 as finance terms and conditions, and countries' exposure to physical impacts of climate change 5 overall, result in a worsening outlook for a global just transition (high confidence). Decarbonising 6 the economy requires global action to address fundamental economic inequities and overcome the 7 climate investment trap that exists for many developing countries. For these countries the costs and 8 risks of financing often represent a significant challenge for stakeholders at all levels. This challenge is 9 exacerbated by these countries' general economic vulnerability and indebtedness. The rising public 10 fiscal costs of mitigation, and of adapting to climate shocks, is affecting many countries and worsening 11 public indebtedness and country credit ratings at a time when there were already significant stresses on 12 public finances. The COVID-19 pandemic has made these stresses worse and tightened public finances 13 still further. Other major challenges for commercial climate finance include: the mismatch between capital and investment needs, home bias23 14 considerations, differences in risk perceptions for regions, as 15 well as limited institutional capacity to ensure safeguards are effective. (high confidence) {15.2, 15.6.3} 16 | Heritage | 184 - 186 |

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| IPCC | IPCC_AR6_WGIII_Full_ Report | 5 Addressing these drivers can enable diverse communities, sectors, stakeholders, regions and cultures to 6 participate in just, equitable and inclusive processes that improve the health and well-being of people 7 and the planet. Looking at climate change from a justice perspective also means placing the emphasis 8 on: i) the protection of vulnerable populations from the impacts of climate change, ii) mitigating 9 the effects of low-carbon transformations, and iii) ensuring an equitable decarbonised world (high 10 confidence). {17.1} The SDG framework25 11 can serve as a template to evaluate the long-term implications of mitigation 12 on sustainable development and vice versa (high confidence). Understanding the co-benefits and 13 trade-offs associated with mitigation is key to understanding how societies prioritise among the 14 various sectoral policy options (medium confidence). Areas with anticipated trade-offs include food 15 and biodiversity, energy affordability/access, and mineral resource extraction. Areas with anticipated 16 co-benefits include health, especially regarding air pollution, clean energy access and water availability. | Heritage | 197 - 197 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | development outcomes in the longer term (high confidence). Ambitious 29 mitigation can be considered a precondition for achieving the SDGs. {3.7} 30 Adopting coordinated cross-sectoral approaches to climate mitigation can target synergies and 31 minimise trade-offs, both between sectors and between sustainable development objectives (high 32 confidence). This requires integrated planning using multiple-objective-multiple-impact policy 33 frameworks. Strong inter-dependencies and cross-sectoral linkages create both opportunities for 34 synergies and need to address trade-offs related to mitigation options and technologies. This can only 35 be done if coordinated sectoral approaches to climate change mitigation policies are adopted that 36 mainstream these interactions and ensure local people are involved in the development of new products, 37 as well as production and consumption practices. For instance, there can be many synergies in urban 38 areas between mitigation policies and the SDGs but capturing these depends on the overall planning of 39 urban structures and on local integrated policies such as combining affordable housing and spatial 40 planning with walkable urban areas, green electrification and clean renewable energy (medium 41 confidence). Integrated planning and cross-sectoral alignment of climate change policies are also 42 particularly evident in developing countries' NDCs under the Paris Agreement, where key priority 43 sectors such as agriculture and energy are closely aligned with the proposed mitigation and adaptation 44 actions and the SDGs. {12.6.2, Supplementary Material Table 17.1, 17.3.3} 45 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Technical Summary IPCC AR6 WG III Do Not Cite, Quote or Distribute TS-136 Total pages: 142 1 2 Figure TS.30: Impacts on SDGs of mitigation likely limiting warming to 1.5°C with narrow mitigation 3 policies vs broader sustainable development policies 4 5 Figure TS.30 legend: Left: benefits of mitigation from avoided impacts. Middle: sustainability co-benefits and 6 trade-offs of narrow mitigation policies (averaged over multiple models). Right: sustainability co-benefits and 7 trade-offs of mitigation policies integrating sustainable development goals. Scale: 0% means no change 8 compared to 3°C (left) or current policies (middle and right). Green values correspond to proportional 9 improvements, red values to proportional worsening. Note: only the left panel considers climate impacts on 10 sustainable development; the middle and right panels do not. "Res' C&P" stands for Responsible Consumption 11 and Production (SDG 12). {Figure 3.39} 12 13 The feasibility of deploying response options is shaped by barriers and enabling conditions across 14 geophysical, environmental-ecological, technological, economic, socio-cultural, and institutional 15 dimensions (high confidence). Accelerating the deployment of response options depends on reducing 16 or removing barriers across these dimensions, as well on establishing and strengthening enabling 17 conditions. Feasibility is context-dependent, and also depends on the scale and the speed of 18 implementation. For example: the institutional, legal and administrative capacity to support deployment 19 varies across countries; the feasibility of options that involve large-scale land use changes is highly 20 context dependent; spatial planning has a higher potential in early stages of urban development; the 21 geophysical potential of geothermal is site specific; and cultural and local conditions may either inhibit 22 or enable demand-side responses. Figure TS.31 summarises the assessment of barriers and enablers for 23 a broad range of sector specific, and cross sectoral response options. (Box TS.15) {6.4, 7.4, 8.5, 9.10, 24 10.8, 12.3} 25 26 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Technical Summary IPCC AR6 WG III Do Not Cite, Quote or Distribute TS-137 Total pages: 142 1 2 3 Figure TS.31 Geophysical, environmental-ecological, technological, economic, socio-cultural and 4 institutional factors can enable or act as barriers to the deployment of response options 5 Figure TS.31 legend: chapter-level assessment for selected mitigation options. Overlaps may exist in the 6 mitigation options assessed and presented by sector and system, and feasibility might differ depending on the 7 demarcation of that option in each sector. Chapters 6, 8, 9, 10, and 12 assess mitigation response options across 8 six feasibility dimensions: geophysical, environmental-ecological, technological, economic, socio-cultural and 9 institutional. AFOLU (Ch7) and industry (Ch11) are not included because of the heterogeneity of options in 10 these sectors. For each dimension, a set of feasibility indicators was identified. | Heritage | 199 - 202 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | 26 Recent Assessments (IPCC 2014a, 2018b) began to consider the role of individual behavioural choices 27 and cultural norms in driving energy and food patterns. Notably, SR1.5 (Section 4.4.3 in Chapter 4) 28 outlined emerging evidence on the potential for changes in behaviour, lifestyle and culture to contribute 29 to decarbonisation (and lower the cost); for the first time, AR6 devotes a whole chapter (Chapter 5) to 30 consider these and other underlying drivers of energy demand, food choices and social aspects. | Heritage | 215 - 215 |

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| IPCC | IPCC_AR6_WGIII_Full_Report | 38 1.4.7 Social innovation and behaviour change 39 Social and psychological factors affect both perceptions and behaviour (Whitmarsh et al. 2021; Weber 40 2015). Religion, values, culture, gender, identity, social status and habits strongly influence individual 41 behaviours and choices and therefore, sustainable consumption (Section 1.6.3.1 in this chapter and Section 42 5.2 in Chapter 5). Identities can provide powerful attachments to consumption activities and objects that 43 inhibit shifts away from them (Stoll-Kleemann and Schmidt 2017; Ruby et al. 2020; Brekke et al. 2003; ACCEPTED VERSION SUBJECT TO FINAL EDITS Final Government Distribution Chapter 1 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 1-30 Total pages: 106 1 Bénabou and Tirole 2011). Consumption is a habit-driven and social practice rather than simply a set of 2 individual decisions, making shifts in consumption harder to pursue (Evans et al. 2012; Shove and Spurling 3 2013; Kurz et al. 2015; Warde 2017; Verplanken and Whitmarsh 2021). Finally, shifts towards low-carbon 4 behaviour are also inhibited by social-psychological and political dynamics that cause individuals to ignore 5 the connections from daily consumption practices to climate change impacts (Norgaard 2011; Brulle and 6 Norgaard 2019). | Heritage | 235 - 236 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 8 2019; Eshel et al. 2019) however, diets are deeply entrenched in cultures and identities and hard to change 9 (Fresco 2015; Mylan 2018). Changing diets also raises cross-cultural ethical issues, in addition to meat's 10 role in providing nutrition (Plumwood 2004). Henceforth, some behaviours that are harder to change will 11 only be transformed by the transition itself: triggered by policies, the transition will bring about 12 technologies that, in turn, will entrench new sustainable behaviours. | Heritage | 236 - 236 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 25 Source: IPCC 2018b 26 27 Other concepts such as "Doughnut Economics" (Raworth 2018), ecological modernisation, and 28 mainstreaming are also used to convey ideals of development pathways that take sustainability, climate 29 mitigation, and environmental limits seriously (Dale et al. 2015a). Mainstreaming focuses on ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 1 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 1-41 Total pages: 106 1 incorporating climate change into national development activities, such as the building of infrastructure 2 (Wamsler and Pauleit 2016; Runhaar et al. 2018). The 'green economy' and green growth – growth 3 without undermining ecological systems, partly by gaining economic value from cleaner technologies 4 and systems and is inclusive and equitable in its outcomes - has gained popularity in both developed 5 and developing countries as an approach for harnessing economic growth to address environmental 6 issues (Bina 2013; Georgeson et al. 2017; Capasso et al. 2019; Song et al. 2020; Hao et al. 2021). Critics 7 however argue that green economy ultimately emphasises economic growth to the detriment of other 8 important aspects of human welfare such as social justice (Adelman 2015; Death 2014; Kamuti 2015), 9 and challenge the central idea that it is possible to decouple economic activity and growth (measured 10 as GDP increment) from increasing use of biophysical resources (raw materials, energy) (Jackson and 11 Victor 2019; Parrique et al. 2019; Hickel and Kallis 2020; Haberl et al. 2020; Vadén et al. 2020). | Heritage | 246 - 247 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 5 6 2.5.3.3 Granular technologies improve faster 7 The array of evidence of technology learning that has accumulated both before and since AR5 8 (Thomassen et al., 2020) has prompted investigations about the factors that enable rapid technology 9 learning. From the wide variety of factors considered, unit size has generated the strongest and most 10 robust results. Smaller unit sizes, sometimes referred to as 'granularity', tend to be associated with faster 11 learning rates (medium confidence) (Sweerts et al., 2020; Wilson et al., 2020). Examples include solar 12 PV, batteries, heat pumps, and to some extent wind power. The explanatory mechanisms for these 13 observations are manifold and well established: more iterations are available with which to make 14 improvements (Trancik, 2006); mass production can be more powerful than economies of scale 15 (Dahlgren et al., 2013); project management is simpler and less risky (Wilson et al., 2020); the ease of 16 early retirement can enable risk-taking for innovative designs (Sweerts et al., 2020); and they tend to 17 be less complicated (Malhotra and Schmidt, 2020; Wilson et al., 2020). Small technologies often 18 involve iterative production processes with many opportunities for learning by doing and have much of 19 the most advanced technology in the production equipment than in the product itself. In contrast, large 20 unit scale technologies – such as full-scale nuclear power, CCS, low-carbon steel making, and negative 21 emissions technologies such as bioenergy with carbon capture and sequestration (BECCS) – are often 22 primarily built on site and include thousands to millions of parts such that complexity and system 23 integration issues are paramount (Nemet, 2019). Despite the accumulating evidence of the benefits of 24 granularity, these studies are careful to acknowledge the role of other factors in explaining learning. In 25 a study of 41 energy technologies (Figure 2.23), unit size explained 22% of the variation in learning 26 rates (Sweerts et al., 2020) and a study of 31 low-carbon technologies showed unit size explained 33% 27 (Wilson et al., 2020). Attributing that amount of variation to a single factor is rare in studies of 28 technological change. The large residual has motivated studies, which find that small-scale technologies 29 provide opportunities for rapid change, but they do not make rapid change inevitable; a supportive 30 context, including supportive policy and complementary technologies, can stimulate more favourable 31 technology outcomes (high confidence). | Heritage | 371 - 371 |

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| Organisation | Document | Quotation Content | Codes | Page |
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| IPCC | IPCC_AR6_WGIII_Full_ Report | 4 Status Competition. As part of a larger consumer society and consumer culture, based on consumer- 5 oriented lifestyles, products frequently provide a source for identity and fulfilment (Stearns, 2001; 6 Baudrillard, 2017; Jorgenson et al., 2019). People pursue cultural constructs such as status, comfort, 7 convenience, hygiene, nutrition, and necessity. Consumption is, by and large, not an end in itself but a 8 means to achieve some other end, and those ends are diverse and not necessarily connected to one 9 another (Wilk, 2010). This shows that consumption patterns cannot be sufficiently understood without 10 also considering the context, for example the cultural and social contexts leading to status competition 11 and status-related consumption (Veblen, 2009; Schor and J.B., 2015; Wilk, 2017). Status seeking can 12 work to reduce emissions when 'green products' such as an electric car or photovoltaics on the roof 13 become a sign for high-status (Griskevicus Tybur, and Van Den Bergh, 2010). It also can work to 14 increase emissions through visible and high-carbon intensive consumption items such a larger homes, 15 fuel-inefficient SUVs cars, and long-distance vacations (Schor, 1998), driven by a notion of having 'to 16 keep up with the Joneses'(Hamilton, 2011). This can lead to formation of new habits and needs, where 17 products and services become normalized and are quickly perceived as needed, reinforced through 18 social networks and advertisement, making it psychologically easy to convert a luxury item to a 19 perceived necessity (Assadour, 2012). For example, the share of adults who consider a microwave a 20 necessity was about one third in 1996 but had increased to more than two thirds in 2006, but retreated 21 in importance during the recession years 2008-2009 (Morin and Taylor, 2009). Similar ups and downs 22 have been observed for television sets, air conditioning, dishwasher or the clothes dryer. (Druckman 23 and Jackson, 2009). What is considered a basic need and what is a luxury is subject to change over 24 one's lifetime and in relation to others (Horowitz, 1988). This shows that the boundaries of public's 25 luxury-versus-necessity perceptions are malleable (Morin and Taylor, 2009). | Heritage | 379 - 379 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | 26 Inequality. Global inequality within and between countries has shifted over the last decades expanding 27 consumption and consumer culture (Castilhos and Fonseca, 2016; Alvaredo et al., 2018; Short and 28 Martínez, 2020). The rise of middle class income countries, mostly in Asia, eg. China, India, Indonesia 29 and Vietnam, and the stagnating incomes of the middle classes in developed economies reduced 30 between countries income differences; meanwhile the population under extreme poverty (threshold of 31 1.9 USD per person/day) is now concentrated in Sub-Saharan Africa and South Asia (Milanović, 2016). | Heritage | 379 - 379 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | 9 Sources: (Luderer et al., 2018; Tong et al., 2019) Future CO2 emissions from existing and planned fossil fuel infrastructure (accounting studies) Residual fossil fuel emissions - cumulative gross CO2 emissions from fossil fuel and industry until reaching net zero CO2 emissions (in GtCO2) Tong et al. (2019) Early strengthening from (2020) Delayed strengthening from 2030 GtCO2 Year Well below 2°C Below 1.5°C in 2100 Well below 2°C Below 1.5°C in 2100 Existing AND proposed Electricity 550 Existing AND future instalments Electricity 180 130 250 200 (380-730) 2018 (140 - 310) (90 - 160) (220 - 340) (190 - 230) Non-electric supply Non-electric supply 100 59 120 75 (42 - 130) (27 - 83) (55 - 150) (40 - 100) Existing Industry 160 Industry 260 140 290 200 (110-220) 2017 (160 - 330) (86 - 180) (200 - 370) (130 - 250) Transportation 64 Transportation 310 170 310 200 (53-75) 2017 (190 - 370) (110 - 220) (250 - 400) (140 - 260) Buildings 74 Buildings 110 58 120 73 (52-110) 2018 (75 - 110) (35 - 77) (80 - 150) (51 - 93) All sectors and proposed electricity 850 All sectors (2021 – net zero CO2) 960 570 1100 770 (730 - 1100) (400 - 640) (900 - 1200) (590 - 860) All sectors (2021-2100) 1300 850 1400 1000 (600-1,100) (970 - 1500) (650 - 1100) (1200 - 1600) (860 - 1300) Implied minimum requirement for carbon dioxide removal until 2100 150 (0 – 350) 350 (150 – 600) 250 (50 – 450) 500 (360 – 800) 10 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 2 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 2-76 Total pages: 127 1 2 2.8 Climate and Non-Climate Policies and Measures and their Impacts on 3 Emissions 4 2.8.1 Introduction 5 The key to achieving climate change mitigation targets includes crafting environmentally effective, 6 economically efficient and socially equitable policies. For the purposes of this section, policies are 7 defined broadly as actions to guide decisions to reach explicit goals and, accordingly, climate 8 (mitigation) policies are the ones whose primary objective is to reduce GHG emissions. They include a 9 range of domains from economic and institutional to R&D and social policies and are implemented by 10 various instruments (e.g., market-based and regulatory in the economic domain) and measures (e.g., 11 legal provisions and governance arrangements in the institutional domain) (see Chapter 13 and the 12 Glossary about mitigation policies). Yet GHG emissions are also affected by policies enacted in various 13 social, economic, and environmental areas to pursue primarily non-climatic objectives. This section 14 presents succinct assessments of the outcomes and effectiveness of a few selected policy instruments 15 applied in the last two decades targeting climate protection (Sections 2.8.2 and 2.8.3) and GHG 16 emissions impacts of selected other policies primarily aiming improvements in environmental quality and natural resource management (Section 2.8.4).12 17 18 It is rather difficult, though not impossible, to discern the genuine impacts of climate and non-climate 19 policies on GHG emissions. Most of current and past policies target only a small part of global emissions 20 in a limited geographical area and/or from a small number of economic sectors. However, in addition to 21 the targeted region or sector, policies and measures tend to affect GHG emissions in other parts of the 22 world. Emissions leakage is the key channel by which such phenomena and complex interactions occur. 23 13 Uncertainties in impacts, synergies, and trade-offs between policies and measures also 24 complicate the evaluation of emissions impacts. These make it challenging to identify the impacts of 25 any specific policy or measure on emissions of any specific region or sector. Rigorous statistical analyses 26 are necessary for building strong empirical evidence, but the experience with climate-related policy 27 experiments to date is limited. | Heritage | 387 - 388 |

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| IPCC | IPCC_AR6_WGIII_Full_Report | 12 Forestry case: zero deforestation 13 Forest is generally defined as land spanning more than 0.5 hectares with trees higher than 5 meters and 14 a canopy cover of more than 10%, or trees able to reach these thresholds in situ (FAO, 1998). Zero- 15 deforestation (i.e., both gross and net zero deforestation) initiatives generate results at multiple levels 16 (Meijer, 2014). Efforts to achieve zero-deforestation (and consequently emissions) are announced by 17 NGOs, companies, governments, and other stakeholder groups. NGOs engage through their 18 campaigning, but also propose tools and approaches for companies (Leijten et al., 2020). The extent to 19 which companies can actually monitor actions conducive to zero-deforestation pledges depends on their 20 position in the supply chain. Beyond the business practices of participating companies, achieving long- 21 term positive societal impacts requires upscaling from supply chains towards landscapes, with 22 engagement of all stakeholders, and in particular small producers. The various success indicators for 23 zero deforestation mirror the multiple levels at which such initiatives develop: progress towards 24 certification, improved traceability, and legality are apparent output measures, whereas direct-area 25 monitoring and site selection approaches target the business practices themselves. | Heritage | 393 - 393 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 44 45 3.3.2.3 The timing of net zero emissions 46 47 In addition to the constraints on change in global mean temperature, the Paris Agreement also calls for 48 reaching a balance of sources and sinks of GHG emissions (Art. 4). Different interpretations of the 49 concept related to balance have been published (Rogelj et al. 2015c; Fuglestvedt et al. 2018). Key 50 concepts include that of net zero CO2 emissions (anthropogenic CO2 sources and sinks equal zero) 51 and net zero greenhouse gas emission (see also Annex I Glossary and Box 3.3). The same notion can 52 be used for all GHG emissions, but here ranges also depend on the use of equivalence metrics 53 (Chapter 2, Box 2.2). Moreover, it should be noted that while reaching net zero CO2 emissions 54 typically coincides with the peak in temperature increase; net zero GHG emissions (based on GWP- 55 100) implies a decrease in global temperature (Riahi et al. 2021) and net zero GHG emission typically ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 3 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 3-37 Total pages: 156 1 requires negative CO2 emissions to compensate for the remaining emissions from other GHGs. Many 2 countries have started to formulate climate policy in the year that net zero emissions (either CO2 or all 3 greenhouse gases) are reached – although, at the moment, formulations are often still vague (Rogelj et 4 al. 2021). There has been increased attention on the timing of net zero emissions in the scientific 5 literature and ways to achieve it. | Heritage | 475 - 476 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 6 2018a), while others do not—citing concerns around its feasibility due to limited potential sites and 7 issues related to socio-political acceptance—, and rather point to very ambitious increase in renewable 8 energy, which in turn could pose significant challenges in systematically integrating renewable energy 9 into the current energy systems (Viebahn et al. 2014; Mathur and Shekhar 2020). Some limitations of 10 CCS, including uncertain costs, lifecycle and net emissions, other biophysical resource needs, and social 11 acceptance are acknowledged in existing studies (Sekera and Lichtenberger 2020; Jacobson 12 2019;Viebahn et al. 2014; Mathur and Shekhar 2020) 13 While national mitigation portfolios aiming at net zero emissions or lower will need to include some 14 level of CDR, the choice of methods and the scale and timing of their deployment will depend on the 15 ambition for gross emission reductions, how sustainability and feasibility constraints are managed, and 16 how political preferences and social acceptability evolve (Cross-Chapter Box 8). Furthermore, 17 mitigation deterrence may create further uncertainty, as anticipated future CDR could dilute incentives 18 to reduce emissions now (Grant et al. 2021), and the political economy of net negative emissions has 19 implications for equity (Mohan et al. 2021). | Heritage | 640 - 640 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 23 Obstacles to the implementation of accelerated mitigation pathways can be grouped in four main 24 categories (Table 4.10). The first set of arguments can be understood through the lens of cost-benefit 25 analysis of decision-makers, as they revolve around the following question: Are costs too high relative 26 to benefits? More precisely, are the opportunity costs—in economics terms, what is being forfeited by 27 allocating scarce resources to mitigation—justified by the benefits for the decision-maker (whether 28 individual, firm, or nation)? This first set of obstacles is particularly relevant because accelerated 29 mitigation pathways imply significant effort in the short-run, while benefits in terms of limited warming 30 accrue later and almost wholly to other actors. However, as discussed in 3.6 and 4.2.6, mitigation costs 31 for a given mitigation target are not carved in stone. They strongly depend on numerous factors, 32 including the way mitigation policies have been designed, selected, and implemented, the processes 33 through which markets have been shaped by market actors and institutions, and nature of socially- and 34 culturally-determined influences on consumer preferences. Hence, mitigation choices that might be 35 expressed straightforwardly as techno-economic decisions are, at a deeper level, strongly conditioned 36 by underlying structures of society. | Heritage | 653 - 653 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 35 Addressing these choices coherently shifts the development pathway away from a continuation of 36 existing trends, 37 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 4 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 4-64 Total pages: 156 1 2 Figure 4.7 Shifting development pathways to increased sustainability: Choices by a wide range of actors 3 at key decision points on development pathways can reduce barriers and provide more tools to accelerate 4 mitigation and achieve other Sustainable Development Goals 5 4.3.1.3 Expanding the range of policies and other mitigative options 6 Shifting development pathways aims to influence the ultimate drivers of emissions (and development 7 generally), such as the systemic and cultural determinants of consumption patterns, the political systems 8 and power structures that govern decision making, the institutions and incentives that guide and 9 constrain socio-technical innovation, and the norms and information platforms that shape knowledge 10 and discourse, and culture, values and needs (Raskin et al. 2002). These ultimate drivers determine the 11 mitigative capacity of a society. | Heritage | 658 - 659 |

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| IPCC | IPCC_AR6_WGIII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 4 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 4-75 Total pages: 156 1 2a. Past development pathways determine both today's GHG emissions and the set of opportunities 2 to reduce emissions 3 4 Development pathways drive GHG emissions for a large part (2.4, 2.5 and 2.6). For example, different 5 social choices and policy packages with regard to land use and associated rents will result in human 6 settlements with different spatial patterns, different types of housing markets and cultures, and different 7 degrees of inclusiveness, and thus different demand for transport services and associated GHG 8 emissions (8.3.1, 10.2.1). | Heritage | 669 - 670 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 33 Because low-carbon transitions are political processes, analyses are needed of policy as well as for 34 policy (13.6). Political scientists have developed a number of theoretical models that both explain 35 policy-making processes and provide useful insights for influencing those processes. Case studies of 36 successes and failures in sustainable development and mitigation offer equally important insights. Both 37 theoretical and empirical analysis reinforce the argument that single policy instruments are not 38 sufficient (robust evidence, high agreement). Policymakers might rather mobilise a range of policies, 39 such as financial instruments (taxes, subsidies, grants, loans), regulatory instruments (standards, laws, 40 performance targets) and processual instruments (demonstration projects, network management, public 41 debates, consultations, foresight exercises, roadmaps) (Voß et al. 2007). Policies can be designed to 42 focus on limiting or phasing out high-carbon technology. The appropriate mix is likely to vary between 43 countries and domains, depending on political cultures and stakeholder configurations (Rogge and 44 Reichardt 2016), but is likely to include a combination of: a) standards, nudges and information to 45 encourage low-carbon technology adoption and behavioural change; b) economic incentives to reward 46 low carbon investments; c) supply-side policy instruments including for fossil fuel production (to<br>ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 4 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 4-82 Total pages: 156 1 complement demand-side climate policies) and d) innovation support and strategic investment to 2 encourage systemic change (Grubb 2014). These approaches can be mutually reinforcing. For example, 3 carbon pricing can incentivise low carbon innovation, while targeted support for emerging niche 4 technologies can make them more competitive encourage their diffusion and ultimately facilitate a 5 higher level of carbon pricing. Similarly, the success of feed-in tariffs in Germany only worked as well 6 as it did because it formed part of a broader policy mix including "supply-push" mechanisms such as 7 subsidies for research and "systemic measures" such as collaborative research projects and systems of 8 knowledge exchange (Rogge et al. 2015). | Heritage | 676 - 677 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 7 Restoration or protection of coastal ecosystems is an important adaptation action with multiple benefits, 8 with bounded global mitigation benefits (Gattuso et al. 2018; Bindoff et al. 2019). Such 9 restoration/preservation reduces coastal erosion and protects from storm surges, and otherwise mitigates 10 impacts of sea level rise and extreme weather along the coast line (Siikamäki et al. 2012; Romañach et 11 al. 2018; Alongi 2008). Restoration of tidal flow to coastal wetlands inhibits methane emissions which 12 occur in fresh and brackish water (Kroeger et al. 2017) (7.4.2.8 describes a more inclusive set of 13 ecosystem services provided by coastal wetlands). Coastal habitat restoration projects can also provide 14 significant social benefits in the form of job creation (through tourism and recreation opportunities), as 15 well as ecological benefits through habitat preservation (Edwards et al. 2013; Sutton-Grier et al. 2015; 16 Sutton-Grier and Moore 2016; Kairo et al. 2018; Wylie et al. 2016; Bindoff et al. 2019). | Heritage | 691 - 691 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 47 Claims on the benefits of the circular economy for sustainability and climate change mitigation have 48 limited evidence. {5.3.4, 5.3.4.1, 5.3.4.2, Figure 5.12, Figure 5.13} 49 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 5 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 5-4 Total pages: 192 1 Social aspects of demand-side mitigation actions 2 3 Decent living standards (DLS) and well-being for all are achievable through the implementation 4 of high-efficiency low demand mitigation pathways (medium confidence). Decent Living Standards 5 (DLS) – a benchmark of material conditions for human well-being – overlaps with many Sustainable 6 Development Goals (SDGs). Minimum requirements of energy use consistent with enabling well-being for all is between 20 and 50 GJ cap-1 yr-1 7 depending on the context. {5.2.2.1, 5.2.2.2, Box 5.3} 8 9 Providing better services with less energy and resource input has high technical potential and is 10 consistent with providing well-being for all (medium confidence). Assessment of 19 demand-side 11 mitigation options and 18 different constituents of well-being show that positive impacts on well-being 12 outweigh negative ones by a factor of 11. {5.2, 5.2.3, Figure 5.6,} 13 14 Demand-side mitigation options bring multiple interacting benefits (high confidence). Energy 15 services to meet human needs for nutrition, shelter, health, etc. are met in many different ways with 16 different emissions implications that depend on local contexts, cultures, geography, available 17 technologies, social preferences. In the near term, many less-developed countries and poor people 18 everywhere require better access to safe and low-emissions energy sources to ensure decent living 19 standards and increase energy savings from service improvements by about 20-25%. {5.2, 5.4.5, Figure 20 5.3, Figure 5.4, Figure 5.5, Figure 5.6, Box 5.2, Box 5.3} 21 22 Granular technologies and decentralized energy end-use, characterised by modularity, small unit 23 sizes and small unit costs, diffuse faster into markets and are associated with faster technological 24 learning benefits, greater efficiency, more opportunities to escape technological lock-in, and 25 greater employment (high confidence). Examples include solar photovoltaic systems, batteries, and 26 thermal heat pumps. {5.3, 5.5, 5.5.3} 27 28 Wealthy individuals contribute disproportionately to higher emissions and have a high potential 29 for emissions reductions while maintaining decent living standards and well-being (high 30 confidence). Individuals with high socio-economic status are capable of reducing their GHG emissions 31 by becoming role models of low-carbon lifestyles, investing in low-carbon businesses, and advocating 32 for stringent climate policies. {5.4.1, 5.4.3, 5.4.4, Figure 5.14} 33 34 Demand-side solutions require both motivation and capacity for change (high confidence). | Heritage | 754 - 755 |

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| IPCC | IPCC_AR6_WGIII_Full_ Report | Preferences are malleable and can align with a cultural   ACCEPTED VERSION   SUBJECT TO FINAL EDITS Final Government Distribution Chapter 5 IPCC AR6 WGIII  Do Not Cite, Quote or Distribute 5-6 Total pages: 192  1 shift. The modelling of such shifts by salient and respected community members can help bring about   2 changes in different service provisioning systems. Between 10% and 30% of committed individuals are   3 required to set new social norms. {5.2.1, 5.4}  4  5 Preconditions and instruments to enable demand-side transformation  6  7 Social equity reinforces capacity and motivation for mitigating climate change (medium   8 confidence). Impartial governance such as fair treatment by law and order institutions, fair treatment   9 by gender, and income equity, increases social trust, thus enabling demand-side climate policies. High   10 status (often high carbon) item consumption may be reduced by taxing absolute wealth without   11 compromising well-being. {5.2, 5.4.2, 5.6}  12  13 Policies that increase the political access and participation of women, racialized, and marginalised   14 groups, increase the democratic impetus for climate action. (high confidence). Including more   15 differently situated knowledge and diverse perspectives makes climate mitigation policies more   16 effective. {5.2, 5.6}  17  18 Carbon pricing is most effective if revenues are redistributed or used impartially (high   19 confidence). A carbon levy earmarked for green infrastructures or saliently returned to taxpayers   20 corresponding to widely accepted notions of fairness increases the political acceptability of carbon   21 pricing. {5.6, Box 5.11}   22  23 Greater contextualisation and granularity in policy approaches better addresses the challenges   24 of rapid transitions towards zero-carbon systems (high confidence). Larger systems take more time   25 to evolve, grow, and change compared to smaller ones. Creating and scaling up entirely new systems   26 takes longer than replacing existing technologies and practices. Late adopters tend to adopt faster than   27 early pioneers. Obstacles and feasibility barriers are high in the early transition phases. Barriers decrease   28 as a result of technical and social learning processes, network building, scale economies, cultural   29 debates, and institutional adjustments. {5.5, 5.6}  30  31 The lockdowns implemented in many countries in response to the COVID-19 pandemic   32 demonstrated that behavioural change at a massive scale and in a short time is possible (high   33 confidence). COVID-19 accelerated some specific trends, such as an uptake in urban cycling. However,   34 the acceptability of collective social change over a longer term towards less resource-intensive lifestyles   35 depends on social mandate building through public participation, discussion and debate over   36 information provided by experts, to produce recommendations that inform policy-making. {Box 5.2}  37  38 Mitigation policies that integrate and communicate with the values people hold are more   39 successful (high confidence). Values differ between cultures. Measures that support autonomy, energy   40 security and safety, equity and environmental protection, and fairness resonate well in many   41 communities and social groups. Changing from a commercialised, individualised, entrepreneurial   42 training model to an education cognizant of planetary health and human well-being can accelerate   43 climate change awareness and action {5.4.1, 5.4.2}  44  45 Changes in consumption choices that are supported by structural changes and political action   46 enable the uptake of low-carbon choices (high confidence). Policy instruments applied in   47 coordination can help to accelerate change in a consistent desired direction. Targeted technological   48 change, regulation, and public policy can help in steering digitalization, the sharing economy, and   49 circular economy towards climate change mitigation. {5.3, 5.6}  50 ACCEPTED VERSION   SUBJECT TO FINAL EDITS Final Government Distribution Chapter 5 IPCC AR6 WGIII  Do Not Cite, Quote or Distribute 5-7 Total pages: 192  1 Complementarity in policies helps in the design of an optimal demand-side policy mix (medium   2 confidence). In the case of energy efficiency, for example, this may involve CO2 pricing, standards and   3 norms, and information feedback.{5.3, 5.4, 5.6}  4  5  ACCEPTED VERSION   SUBJECT TO FINAL EDITS Final Government Distribution Chapter 5 IPCC AR6 WGIII  Do Not Cite, Quote or Distribute 5-8 Total pages: 192  1 5.1 Introduction  2 The Sixth Assessment Report of the IPCC (AR6), for the first time, features a chapter on demand,   3 services, and social aspects of mitigation. It builds on the AR4, which linked behaviour and | Heritage | 756 - 759 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | 31 2014). In this chapter, service-related mitigation strategies are categorized as Avoid, Shift, or Improve   32 (ASI) options to show how mitigation potentials, and social groups who can deliver them, are much   33 broader than usually considered in traditional sector-specific presentations. ASI originally arose from   34 the need to assess the staging and combinations of interrelated mitigation options in the provision of   35 transportation services (Hidalgo and Huizenga 2013). In the context of transportation services, ASI   36 seeks to mitigate emissions through avoiding as much transport service demand as possible (e.g.,   37 telework to eliminate commutes, mixed-use urban zoning to shorten commute distances), shifting  38 remaining demand to more efficient modes (e.g., bus rapid transit replacing passenger vehicles), and   39 improving the carbon intensity of modes utilised (e.g., electric buses powered by renewables) (Creutzig   40 et al. 2016a). This chapter summarises ASI options and potentials across sectors and generalises the   41 definitions. 'Avoid' refers to all mitigation options that reduce unnecessary (in the sense of being not   42 required to deliver the desired service output) energy consumption by redesigning service provisioning   43 systems; 'shift' refers to the switch to already existing competitive efficient technologies and service   44 provisioning systems; and 'improve' refers to improvements in efficiency in existing technologies. The   45 Avoid-Shift-Improve framing operates in three domains: 'Socio-cultural', where social norms, culture,   46 and individual choices play an important role – a category especially but not only relevant for avoid   47 options; 'Infrastructure', which provides the cost and benefit landscape for realising options and is   48 particularly relevant for shift options; and 'Technologies', especially important for the improve options. | Heritage | 760 - 760 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | 49 Avoid, Shift, and Improve choices will be made by individuals and households, instigated by salient   50 and respected role models and novel social norms, but require support by adequate infrastructures   ACCEPTED VERSION   SUBJECT TO FINAL EDITS Final Government Distribution Chapter 5 IPCC AR6 WGIII  Do Not Cite, Quote or Distribute 5-10 Total pages: 192  1 designed by urban planners and building and transport professionals, corresponding investments, and a   2 political culture supportive of mitigation action. This is particularly true for many Avoid and Shift   3 decisions that are difficult because they encounter psychological barriers of breaking routines, habits   4 and imagining new lifestyles and the social costs of not conforming to society (Kaiser 2006). Simpler   5 Improve decisions like energy efficiency investments on the other hand can be triggered and sustained   6 by traditional policy instruments complemented by behavioural nudges. | Heritage | 760 - 761 |

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| IPCC | IPCC_AR6_WGIII_Full_ Report | 40 nutrition, shelter, health, etc.), recognising that these service needs may be met in many different ways 41 (with different emissions implications) depending on local contexts, cultures, geography, available 42 technologies, social preferences, and other factors. Therefore, one key way of thinking about providing 43 well-being for all with low carbon emissions centres around prioritising ways of providing services for 44 DLS in a low-carbon way (including choices of needs satisfiers, and how these are provided or made 45 accessible). They may be supplied to individuals or groups / communities, both through formal markets 46 and/or informally, e.g. by collaborative work, in coordinated ways that are locally-appropriate, designed 47 and implemented in accordance with overlapping local needs. | Heritage | 768 - 768 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | 2 2019b; Millward-Hopkins et al. 2020), which shows the level of inequality that exists; this depends on 3 the context such as geography, culture, infrastructure or how services are provided (Brand-Correa et al. | Heritage | 771 - 771 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | 47 2020; Stratford 2020; Otto et al. 2019) (see Section 5.2.2.3). Conspicuous consumption by the wealthy 48 is the cause of a large proportion of emissions in all countries, related to expenditures on such things as 49 air travel, tourism, large private vehicles and large homes (Brand and Boardman 2008; Brand and ACCEPTED VERSION SUBJECT TO FINAL EDITS Final Government Distribution Chapter 5 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 5-30 Total pages: 192 1 Preston 2010; Gore 2015; Sahakian 2018; Osuoka and Haruna 2019; Lynch et al. 2019; Roy and Pal 2 2009; Hubacek et al. 2017; Jorgenson et al. 2017; Gössling 2019; Kenner 2019; Roy et al. 2012). | Heritage | 780 - 781 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | 10 Women’s work and decision-making are central in the food chain and agricultural output in most 11 developing countries, and in household management everywhere. Emissions from cooking fuels can 12 cause serious health damages, and unsustainable extraction of biofuels can also hurt mitigation (Bailis 13 et al. 2015), so considering health, biodiversity and climate tr adeoffs and co-benefits is important 14 (Rosenthal et al. 2018; Aberilla et al. 2020; Mazorra et al. 2020) . Policies on energy use and 15 consumption are often focused on technical issues related to energy supply, thereby overlooking 16 ‘demand-side’ factors such as household decision-making, unpaid work, livelihoods and care 17 (Himmelweit 2002; Perch 2011; Fumo 2014; Hans et al. 2019; Huyer and Partey 2020). Such gender- 18 blindness represents the manifestation of wider issues related to political ideology, culture and tradition 19 (Carr and Thompson 2014; Thoyre 2020; Perez et al. 2015; Fortnam et al. 2019). | Heritage | 786 - 786 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | 6 7 8 9 Figure 5.7 Demand-side mitigation options and indicative potentials 10 Mitigation response options related to demand for services have been categorised into three domains: 11 ‘socio-cultural factors’, related to social norms, culture, and individual choices and behaviour; 12 ‘infrastructure use’, related to the provision and use of supporting infrastructure that enables individual 13 choices and behaviour; and ‘technology adoption’, which refers to the uptake of technologies by end 14 users. Potentials in 2050 are estimated using the International Energy Agency’s 2020 World Energy 15 Outlook STEPS (Stated Policy Scenarios) as a baseline. This scenario is based on a sector-by-sector 16 assessment of specific policies in place, as well as those that have been announced by countries by mid- 17 2020. This scenario was selected due to the detailed representation of options across sectors and sub- 18 sectors. The heights of the coloured columns represent the potentials on which there is a high level of 19 agreement in the literature, based on a range of case studies. The range shown by the dots connected by 20 dotted lines represents the highest and lowest potentials reported in the literature which have low to 21 medium levels of agreement. The demand side potential of socio-cultural factor in food has two parts. | Heritage | 793 - 793 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | 13 14 15 5.4 Transition toward high well-being and low-carbon demand societies 16 Demand-side mitigation involves individuals (e.g. consumption choices), culture (e.g. social norms, 17 values), corporate (e.g. investments), institutions (e.g. political agency), and infrastructure change (high 18 evidence, high agreement). These five drivers of human behaviour either contribute to the status-quo of 19 a global high-carbon, consumption, and GDP growth oriented economy or help generate the desired 20 change to a low-carbon energy-services, well-being, and equity oriented economy (Jackson 2017; 21 Cassiers et al. 2018; Yuana et al. 2020)(Figure 5.14). Each driver has novel implications for the design 22 and implementation of demand-side mitigation policies. They show important synergies, making energy 23 demand mitigation a dynamic problem where the packaging and/or sequencing of different policies play 24 a role in their effectiveness, demonstrated in Sections 5.5 and 5.6. The Social Science Primer 25 (Supplementary Material I Chapter 5) describes theory and empirical insights about the interplay 26 between individual agency, the social and physical context of demand-side decisions in the form of 27 social roles and norms, infrastructure and technological constraints and affordances, and other formal 28 and informal institutions. Incremental interventions on all five fronts change social practices, effecting 29 simultaneously energy and well-being (Schot and Kanger 2018). Transformative change will require 30 coordinated use of all five drivers, as described in Figure 5.14 and Table 5. using novel insights about 31 behaviour change for policy design and implementation (high evidence, high agreement). In particular, 32 socio-economic factors, such as equity, public service quality, electricity access and democracy are 33 found to be highly significant in enabling need satisfaction at low energy use, whereas economic growth 34 beyond moderate incomes and extractive economic activities are observed to be prohibiting factors 35 (Vogel et al. 2021). | Heritage | 818 - 818 |

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| Organisation | Document | Quotation Content | Codes | Page |
|---|---|---|---|---|
| IPCC | IPCC_AR6_WGIII_Full_Report | 14 15 START BOX 5.6 HERE 16 17 Box 5.6 Socio-behavioural aspects of deploying cookstoves 18 Universal access to clean and modern cooking energy could cut premature death from household air 19 pollution by two-thirds, while reducing forest degradation and deforestation and contribute to the 20 reduction of up to 50% of CO2 emissions from cooking (relative to baseline by 2030) (IEA 2017c; Hof 21 et al. 2019). However, in the absence of policy reform and substantial energy investments, 2.3 billion 22 people will have no access to clean cooking fuels such as biogas, LPG, natural gas or electricity in 2030 23 (IEA 2017c). Studies reveal that a combination of drivers influence adoption of new cookstove 24 appliances including affordability, behavioural and cultural aspects (lifestyles, social norms around 25 cooking and dietary practices), information provision, availability, aesthetic qualities of the technology, 26 perceived health benefits and infrastructure (spatial design of households and cooking areas). The 27 increasing efficiency improvements in electric cooking technologies, could enable households to shift 28 to electrical cooking at mass scale. The use of pressure cookers and rice cookers is now widespread in 29 South Asia and beginning to penetrate the African market as consumer attitudes are changing towards 30 household appliances with higher energy efficiencies (Batchelor et al. 2019). Shifts towards electric and 31 LPG stoves in Bhutan (Dendup and Arimura 2019), India (Pattanayak et al. 2019), Ecuador (Martínez 32 et al. 2017; Gould et al. 2018) and Ethiopia (Tesfamichael et al. 2021); and improved biomass stoves in 33 China (Smith et al. 1993). Significant subsidy, information (Dendup and Arimura 2019), social 34 marketing and availability of technology in the local markets are some of the key policy instruments 35 helping to adopt ICS (Pattanayak et al. 2019). There is no one-size-fits-all solution to household air 36 pollution – different levels of shift and improvement occur in different cultural contexts, indicating the 37 importance of socio-cultural and behavioural aspects in shifts in cooking practices. See more in 38 Supplementary Material Chapter 5, SM5.6.2. | Heritage | 821 - 821 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 7 8 Core values also influence which costs and benefits are considered (Hahnel et al. 2015; Gölz and Hahnel 9 2016; Steg 2016). Information provision and appeals are thus more effective when tailored to those 10 values (Bolderdijk et al. 2013; Boomsma and Steg 2014), as implemented by the energy-cultures 11 framework (Stephenson et al. 2015; Klaniecki et al. 2020). Awareness, personal norms, and perceived 12 behavioural control predict willingness to change energy-related behaviour above and beyond 13 traditional sociodemographic and economic predictors (Schwartz 1977; Ajzen 1985; Stern 2000), as do 14 perceptions of self-efficacy (Bostrom et al. 2019). However, such motivation for change is often not 15 enough, as actors also need capacity for change and help to overcome individual, institutional and 16 market barriers (Young et al. 2010; Carrington et al. 2014; Bray et al. 2011). | Heritage | 822 - 822 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 26 27 5.4.4 Institutional Drivers 28 The allocation of political power to incumbent actors and coalitions has contributed to lock-in of 29 particular institutions, stabilising the interests of incumbents through networks that include 30 policymakers, bureaucracies, advocacy groups and knowledge institutions (high agreement, high 31 evidence). There is high evidence and high agreement in that institutions are central in addressing 32 climate change mitigation. Indeed, social provisioning contexts including equity, democracy, public 33 services and high quality infrastructure are found to facilitate high levels of need satisfaction at lower 34 energy use, whereas economic growth beyond moderate incomes and dependence on extractive 35 industries inhibit it (Vogel et al. 2021). They shape and interact with technological systems (Unruh 36 2000; Foxon et al. 2004; Seto et al. 2014) and represent rules, norms and conventions that organise and 37 structure actions (Vatn 2015) and help create new path dependency or strengthen existing path 38 dependency (Mattioli et al. 2020) (also see case studies in Box 5.5-5.8 and Supplementary Material 39 Chapter 5). These drive behaviour of actors through formal (e.g., laws, regulations, and standards) or 40 informal (e.g., norms, habits, and customs) processes, and can create constraints on policy options 41 (Breukers and Wolsink 2007). For example, 'the car dependent transport system' is maintained by 42 interlocking elements and institutions, consisting of i) the automotive industry; ii) the provision of car 43 infrastructure; iii) the political economy of urban sprawl; iv) the provision of public transport; v) 44 cultures of car consumption (Mattioli et al. 2020). The behaviour of actors, their processes and 45 implications on policy options and decisions is discussed further in Section 5.6. | Heritage | 836 - 836 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 8 9 From a welfare point of view, infrastructure investments are not constrained by revealed or stated 10 preferences (high evidence, high agreement). Preferences change with social and physical environment, 11 and infrastructure interventions can be justified by objective measures, such as public health and climate 12 change mitigation, not only given preferences (high agreement, high evidence). Specifically, there is a 13 case for more investment in low-carbon transport infrastructure than assumed in environmental 14 economics as it induces low-carbon preferences (Creutzig et al. 2016a; Mattauch et al. 2018, 15 2016). Changes in infrastructure provision for active travel may contribute to uptake of more walking 16 and cycling (Frank et al. 2019). These effects contribute to higher uptake of low-carbon travel options, 17 albeit the magnitude of effects depends on design choices and context (Goodman et al. 2013, 2014; 18 Song et al. 2017; Javaid et al. 2020; Abraham et al. 2021). Infrastructure is thus not only required to 19 make low-carbon travel possible but can also be a pre-condition for the formation of low-carbon 20 mobility preferences (also see mobility case study in Box 5.7). | Heritage | 838 - 838 |
| IPCC | IPCC_AR6_WGIII_Full_Report | Involve arts and humanities to create narratives for policy process Communicate descriptive norms to electricity end users. | Heritage | 839 - 839 |

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| IPCC | IPCC_AR6_WGIII_Full_ Report | 1 2 5.5 An integrative view on transitioning 3 5.5.1 Demand-side transitions as multi-dimensional processes 4 Several integrative frameworks including social practice theory (Røpke 2009; Shove and Walker 2014), 5 the energy cultures framework (Stephenson et al. 2015; Jürisoo et al. 2019) and socio-technical 6 transitions theory (McMeekin and Southerton 2012; Geels et al. 2017) conceptualise demand-side 7 transitions as multi-dimensional and interacting processes (high evidence, high agreement). Social 8 practice theory emphasises interactions between artefacts, competences, and cultural meanings (Røpke 9 2009; Shove and Walker 2014)(Shove and Walker 2014; Røpke 2009). The energy cultures framework 10 highlights feedbacks between materials, norms, and behavioural practices (Stephenson et al. 2015; 11 Jürisoo et al. 2019). Socio-technical transitions theory addresses interactions between technologies, user 12 practices, cultural meanings, business, infrastructures, and public policies (McMeekin and Southerton 13 2012; Geels et al. 2017) and can thus accommodate the five drivers of change and stability discussed in 14 Section 5.4. | Heritage | 840 - 840 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | 15 16 Section 5.4 shows with high evidence and high agreement that the relative influence of different drivers 17 varies between demand-side solutions. The deployment of 'improve' options like LEDs and clean 18 cookstoves mostly involves technological change, adoption by consumers who integrate new 19 technologies in their daily life practices (Smith et al. 1993; Sanderson and Simons 2014; Franceschini 20 and Alkemade 2016), and some policy change. Changes in meanings are less pertinent for those 21 'improve'-options that are primarily about technological substitution. Other improve-options, like clean 22 cookstoves, involve both technological substitution and changes in cultural meanings and traditions. | Heritage | 840 - 840 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 5 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 5-90 Total pages: 192 1 Demand-side transitions involve interactions between radical social or technical innovations (such as 2 the avoid, shift, improve options discussed in Section 5.3) and existing socio-technical systems, energy 3 cultures, and social practices (high evidence, high agreement) (Stephenson et al. 2015; Geels et al. | Heritage | 840 - 841 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | 4 2017). Radical innovations such as tele-working, plant-based burgers, car sharing, vegetarianism, or 5 electric vehicles initially emerge in small, peripheral niches (Kemp et al. 1998; Schot and Geels 2008), 6 constituted by R&D projects, technological demonstration projects (Borghei and Magnusson 2016; 7 Rosenbloom et al. 2018b), local community initiatives or grassroots projects by environmental activists 8 (Hargreaves et al. 2013a; Hossain 2016). Such niches offer protection from mainstream selection 9 pressures and nurture the development of radical innovations (Smith and Raven 2012). Many low- 10 carbon niche-innovations, such as those described in Section 5.3, face uphill struggles against existing 11 socio-technical systems, energy cultures, and social practices that are stabilised by multiple lock-in 12 mechanisms (high evidence, high agreement) (Klitkou et al. 2015; Seto et al. 2016; Clausen et al. 2017; 13 Ivanova et al. 2018). Demand-side transitions therefore do not happen easily and involve interacting 14 processes and struggles on the behavioural, socio-cultural, institutional, business and technological 15 dimensions (Nikas et al. 2020) (see also Section 5.4). | Heritage | 841 - 841 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | 26 The concept of leapfrogging emerged in development economics (Soete 1985), energy policy 27 (Goldemberg 1991) and environmental regulation (Perkins 2003), which provides a first critical review 28 of the concept), and refers to a development strategy that skips traditional and polluting development ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 5 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 5-94 Total pages: 192 1 in favour of the most advanced concepts. For instance, in rural areas without telephone landlines or 2 electricity access (cables), a direct shift to mobile telephony or distributed, locally-sourced energy 3 systems is promoted, or economic development policies for pre-industrial economies forego the 4 traditional initial emphasis of heavy industry industrialisation, instead of focusing on services like 5 finance or tourism. Often leapfrogging is enabled by learning and innovation externalities where 6 improved knowledge and technologies become available for late adopters at low costs. The literature 7 highlights many cases of successful leapfrogging but also highlights limitations (for a review see 8 Watson and Sauter (Watson and Sauter 2011); with example case studies for China e.g. Gallagher 9 (Gallagher 2006) or Chen and Li-Hua (Chen and Li-Hua 2011); Mexico (Gallagher and Zarsky 2007); 10 or Japan and Korea, e.g. Cho et al. (Cho et al. 1998). Increasingly the concept is being integrated into 11 the literature of low-carbon development, including innovation and technology transfer policies (for a 12 review see Pigato (Pigato et al. 2020)), highlighting in particular the importance of contextual factors 13 of successful technology transfer and leapfrogging including: domestic absorptive capacity and 14 technological capabilities (Cirera and Maloney 2017); human capital, skills, and relevant technical 15 know-how (Nelson and Phelps 1966); the size of the market (Keller 2004); greater openness to trade 16 (Sachs and Warner 1995; Keller 2004); geographical proximity to investors and financing (Comin et 17 al. 2012); environmental regulatory proximity (Dechezleprêtre et al. 2015); and stronger protection 18 of intellectual property rights (Dechezleprêtre et al. 2013; Dussaux et al. 2017). The existence of a 19 technological potential for leapfrogging therefore needs to be considered within a wider context of 20 social, institutional, and economic factors that influence if leapfrogging potentials can be realised (high 21 evidence, high agreement). | Heritage | 844 - 845 |

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| IPCC | IPCC_AR6_WGIII_Full_Report | 14 Inclusive and broad-based participation itself also leads to greater social trust and thus is also a key 15 enabler of demand-side climate mitigation (see Section 5.2 for details). Higher social trust and inclusive 16 participatory processes also reduce inequality, restrain opportunistic behaviour and enhance 17 cooperation (Drews and van den Bergh 2016; Gür 2020) (see also Section 5.2). Altogether, broad-based 18 participatory processes are central to the successful implementation of climate policies (Rothstein and 19 Teorell 2008; Klenert et al. 2018) (high evidence , medium agreement). A culture of cooperation feeds 20 back to increase social trust and enables action that reduce GHG emissions (Carattini et al. 2015; Jo and 21 Carattini 2021), and requires including explicit consideration of the informal sector (Box 5.10). More 22 equitable societies also have the institutional flexibility to allow for mitigation to advance faster, given 23 their readiness to adopt locally appropriate mitigation policies; they also suffer less from policy lock-in 24 (Tanner et al. 2009; Lorenz 2013; Chu 2015; Cloutier et al. 2015; Martin 2016; Vandeweerdt et al. | Heritage | 846 - 846 |
| IPCC | IPCC_AR6_WGIII_Full_Report | Use low carbon materials in dwelling design Manufacturing and R&D costs, recycling processes and aesthetic performance (Orsini and Marrone 2019). Access to secondary materials in the building sector (Nußholz et al. | Heritage | 851 - 851 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 39 40 The effectiveness of a policy package is determined by design decisions as well as the wider governance 41 context that include the political environment, institutions for coordination across scales, bureaucratic 42 traditions, and judicial functioning (Howlett and Rayner 2013; Rogge and Reichardt 2013; Rosenow et 43 al. 2016) (high evidence, high agreement). Policy packages often emerge through interactions between 44 different policy instruments as they operate in either complementary or contradictory ways, resulting 45 from conflicting policy goals (Cunningham et al. 2013; Givoni et al. 2013). An example includes the 46 acceleration in shift from traditional biomass to the adoption of modern cooking fuel for 80 million 47 households in rural India over a very short period of 4 years (2016-2020), which employed a 48 comprehensive 'policy package' including financial incentives, infrastructural support and 49 strengthening of the supply chain to induce households to shift towards a clean cooking fuel from the ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 5 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 5-104 Total pages: 192 1 use of biomass (Kumar 2019). This was operationalised by creating a LPG supply chain by linking oil 2 and gas companies with distributors to assure availability, create infrastructure for local storage along 3 with an improvement of the rural road network, especially in the rural context (Sankhyayan and 4 Dasgupta 2019). State governments initiated separate policies to increase the distributorship of LPG in 5 their states (Kumar et al. 2016). Similarly, policy actions for scaling up electric vehicles need to be well 6 designed and coordinated where EV policy, transport policy and climate policy are used together, 7 working on different decision points and different aspects of human behaviour (Barton and Schütte 8 2017). The coordination of the multiple policy actions enables co-evolution of multiple outcomes that 9 involve shifting towards renewable energy production, improving access to charging infrastructure, 10 carbon pricing and other GHG measures (Wolbertus et al. 2018). | Heritage | 854 - 855 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 4 5 6 5.7 Knowledge gaps 7 Knowledge gap 1: Better metric to measure actual human well-being 8 Knowledge on climate action that starts with the social practices and how people live in various 9 environments, cultures, contexts and attempts to improve their well-being, is still in its infancy. In 10 models, climate solutions remain supply-side oriented, and evaluated against GDP, without 11 acknowledging the reduction in well-being due to climate impacts. GDP is a poor metric of human well- 12 being, and climate policy evaluation requires better grounding in relation to decent living standards and 13 or similar benchmarks. Actual solutions will invariably include demand, service provisioning and end 14 use. Literature on how gender, informal economies mostly in developing countries, and solidarity and 15 care frameworks translate into climate action, but also how climate action can improve the life of 16 marginalised groups remains scarce. The working of economic systems under a well-being driven rather 17 than GDP driven paradigm requires better understanding. | Heritage | 856 - 856 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 40 Tolerating ambiguity can be learned, e.g., by interacting with history, poetry and the arts. Sometimes 41 religion and philosophy also help. | Heritage | 857 - 857 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 42 43 As a key enabler, novel narratives created in a variety of ways e.g., by advertising, images, 44 entertainment industry, help to break away from the established meanings, values and discourses and 45 the status quo. For example, discourses that frame comfortable public transport service to avoid stress 46 from driving cars on busy, congested roads help avoid car driving as a status symbol and create a new 47 social norm to shift to public transport. Discourses that portray plant based protein and as healthy and 48 natural promote and stabilise particular diets. Novel narratives and inclusive processes help strategies 49 to overcome multiple barriers. Case studies demonstrate that citizens support transformative changes if 50 participatory processes enable a design that meets local interests and culture. Promising narratives ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 5 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 5-107 Total pages: 192 1 specify that even as speed and capabilities differ humanity embarks on a joint journey towards well- 2 being for all and a healthy planet. | Heritage | 857 - 858 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 24 Solar energy elicits favourable public responses in most countries (high confidence) (Bessette and Arvai 25 2018; Hanger et al. 2016; Jobin and Siegrist 2018; Ma et al. 2015; Mcgowan and Sauter 2005; Hazboun 26 and Boudet 2020; Roddis et al. 2019). Solar energy is perceived as clean and environmentally friendly 27 with few downsides (Faiers and Neame 2006; Whitmarsh et al. 2011b). Key motivations for 28 homeowners to adopt photovoltaic systems are expected financial gains, environmental benefits, the 29 desire to become more self-sufficient, and peer expectations (Korcaj et al. 2015; Palm 2017; Vasseur 30 and Kemp 2015). Hence, the observability of photovoltaic systems can facilitate adoption (Boudet 31 2019). The main barriers to the adoption of solar PV by households are its high upfront costs, aesthetics, 32 landlord-tenant incentives, and concerns about performance and reliability (Whitmarsh et al. 2011b; 33 Vasseur and Kemp 2015; Faiers and Neame 2006). | Heritage | 970 - 970 |

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| IPCC | IPCC_AR6_WGIII_Full_Report | 16 Wind capacity factors have increased over the last decade (Figure 6.11). The capacity factor for onshore 17 wind farms increased from 27% in 2010 to 36% in 2020 (IRENA 2021a). The global average offshore 18 capacity factor has decreased from a peak of 45% in 2017. This has been driven by the increased share 19 of offshore development in China, where projects are often near-shore and use smaller wind turbines 20 than in Europe (IRENA 2021b). Improvements in capacity factors also come from increased 21 functionality of wind turbines and wind farms. Manufactures can adapt the wind turbine generator to 22 the wind conditions. Turbines for windy sites have smaller generators and smaller specific capacity per 23 rotor area, and therefore operate more efficiently and reach full capacity for a longer time period (Rohrig 24 et al. 2019). | Heritage | 972 - 972 |
| IPCC | IPCC_AR6_WGIII_Full_Report | In 2020, typical country-average total installed costs were around USD 1150 kW-1 11 in China and India, and between USD 1403–2472 kW-1 12 elsewhere (IRENA 2021b). Total installed costs of offshore wind 13 farms declined by 12% between 2010 and 2020. But, because some of the new offshore wind projects 14 have moved to deeper waters and further offshore, there are considerable year-to-year variations in their 15 price (IRENA 2021b). Projects outside China in recent years have typically been built in deeper waters 16 (10–55 m) and up to 120 km offshore, compared to around 10 m in 2001–2006, when distances rarely 17 exceeded 20 km. With the shift to deeper waters and sites further from ports, the total installed costs of offshore wind farms rose, from an average of around USD 2500 kW-1 in 2000 to around USD 5127 kW- 18 1 by 2011–2014, before falling to around USD 3185 kW-1 19 in 2020 (IRENA 2020a). The full cost of 20 wind power includes the transmission and system integration costs (Sections 6.4.3, 6.4.6. A new 21 technology in development is the co-location of wind and solar PV power farms, also known as hybrid 22 power plants. Co-locating wind, solar PV, and batteries can lead to synergies in electricity generation, 23 infrastructure, and land usage, which may lower the overall plant cost compared to single technology 24 systems (Lindberg et al. 2021). | Heritage | 973 - 973 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 14 Public support for onshore and particularly offshore wind energy is generally high, although people 15 may oppose specific wind farm projects (high confidence) (e.g., Rand and Hoen 2017; Steg 2018; Bell 16 et al. 2005; Batel and Devine-Wright 2015). People generally believe that wind energy is associated 17 with environmental benefits and that it is relatively cheap. Yet, some people believe wind turbines can 18 cause noise and visual aesthetic pollution, threaten places of symbolic value (Russell et al. 2020; 19 Devine-Wright and Wiersma 2020), and have adverse effects on wildlife (Bates and Firestone 2015), 20 which challenges public acceptability (Rand and Hoen 2017). Support for local wind projects is higher 21 when people believe fair decision-making procedures have been implemented (Aitken 2010a; Dietz and 22 Stern 2008). Evidence is mixed whether distance from wind turbines or financial compensation 23 increases public acceptability of wind turbines (Hoen et al. 2019; Rand and Hoen 2017; Cass et al. | Heritage | 974 - 974 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 10 Hydropower is one of the lowest-cost electricity technologies (Mukheibir 2013; IRENA 2021b). Its operation and maintenance costs are typically 2–2.5% of the investment costs per kW yr-1 11 for a lifetime 12 of 40–80 years (Killingtveit 2020). Construction costs are site specific. The total cost for an installed large hydropower project varies from USD 10,600–804,500 kW-1 13 if the site is located far away from 14 transmission lines, roads, and infrastructure. Investment costs increase for small hydropower plants and may be as high as USD 100,000 kW-1 15 or more for the installation of plants of less than 1 MW - 20% to 16 80% more than for large hydropower plants (IRENA 2015). During the past 100 years, total installed 17 costs and LCOE have risen by a few percent, but the LCOE of hydropower remains lower than the 18 cheapest new fossil fuel-fired option (IRENA 2019b, 2021). | Heritage | 976 - 976 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 43 • Small Modular Reactors. There are more than 70 SMR designs at different stages of consideration 44 and development, from the conceptual phase to licensing and construction of first-of-a-kind 45 facilities (IAEA 2020). Due to smaller unit sizes, the SMRs are expected to have lower total 46 investment costs, although the cost per unit of generation might be higher than conventional large 47 reactors (Mignacca and Locatelli 2020). Modularity and off-site pre-production may allow greater 48 efficiency in construction, shorter delivery times, and overall cost optimization (IEA 2019c). SMR ACCEPTED VERSION SUBJECT TO FINAL EDITS Final Government Distribution Chapter 6 IPCC WGIII AR6 Do Not Cite, Quote or Distribute 6-35 Total pages: 217 1 designs aim to offer an increased load-following capability that makes them suitable to operate in 2 smaller systems and in systems with increasing shares of VRE sources. Their market development 3 by the early 2030s will strongly depend on the successful deployment of prototypes during the 4 2020s. | Heritage | 977 - 978 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 33 Additionally, new technologies are being developed like Enhanced Geothermal Systems (EGS), which 34 is in the demonstration stage (IRENA 2018), deep geothermal technology, which may increase the 35 prospects for harnessing the geothermal potential in a large number of countries, or shallow-geothermal 36 energy, which represents a promising supply source for heating and cooling buildings (Narsilio and Aye 37 2018). Successful large-scale deployment of shallow geothermal energy will depend not only on site- 38 specific economic performance but also on developing suitable governance frameworks (Bloemendal ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 6 IPCC WGIII AR6 Do Not Cite, Quote or Distribute 6-47 Total pages: 217 1 et al. 2018; García-Gil et al. 2020). Technologies for direct uses like district heating, geothermal heat 2 pumps, greenhouses, and other applications are widely used and considered mature. Given the limited 3 number of plants commissioned, economic indicators (Figure 6.15) vary considerably depending on site 4 characteristics. | Heritage | 989 - 990 |

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| IPCC | IPCC_AR6_WGIII_Full_Report | 19 Hydrogen production processes (power-to-gas and vice versa) and hydrogen storage can support short- 20 term and long-term balancing in the energy systems and enhance resilience (Stephen and Pierluigi 2016; 21 Strbac et al. 2020). However, the economic benefits of flexible power-to-gas plants, energy storage, 22 and other flexibility technological and options will depend on the locations of VRE sources, storage 23 sites, gas, hydrogen, and electricity networks (Jentsch et al. 2014; Heymann and Bessa 2015; Ameli et 24 al. 2020). Coordinated operation of gas and electricity systems can bring significant benefits in 25 supplying heat demands. For example, hybrid heating can eliminate investment in electricity 26 infrastructure reinforcement by switching to heat pumps in off-peak hours and gas boilers in peak hours 27 ( Dengiz et al. 2019; Fischer et al. 2017; Bistline et al. 2021). The heat required by direct air carbon 28 capture and storage (DACCS) could be effectively supplied by inherent heat energy in nuclear plants, 29 enhancing overall system efficiency (Realmonte et al. 2019). | Heritage | 992 - 992 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 5 2014). New possibilities are being explored for small-scale PHS installations and expanding the 6 potential for siting (Kougias et al. 2019). For example, in underwater PHS, the upper reservoir is the 7 sea, and the lower is a hollow deposit at the seabed. Seawater is pumped out of the deposit to store off- 8 peak energy and re-enters through turbines to recharge it (Kougias et al. 2019). Using a similar concept, 9 underground siting in abandoned mines and caverns could be developed reasonably quickly (IEA 10 2020h). Storage of energy as gravitational potential can also be implemented using materials other than 11 water, such as rocks and sand. Pumped technology is a mature technology (Barbour et al. 2016; Rehman 12 et al. 2015) and can be important in supporting the transition to future low carbon electricity grids (IHA 13 2021). | Heritage | 997 - 997 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 26 27 Table 6.6 Technical characteristics of a selected range of battery chemistries, categorized as those which 28 precede LIBs (white background), LIBs (yellow background) and post LIBs (blue background). With the 29 exception of the All Solid-State batteries, all use liquid electrolytes. (1 =Mahmoudzadeh et al. 2017; 2 = 30 Manzetti and Mariasiu 2015; 3 =Placke et al. 2017; 4 = Nykvist and Nilsson 2015; 5 =Cano et al. 2018; 6 = 31 BloombergENF 2019; 7 = You and Manthiram 2017; 8 = Fotouhi et al. 2017; 9 = IRENA 2017; 10 = Yang 32 et al., 2020) Battery Type Technology Maturity Life Span (Cycles) Energy Density (Wh L-1 ) Specific Energy (Wh kg-1 ) Price (USD kWh-1 ) in 2017 Lead Acid High 300–800 5 102–106 5 38–60 5 70–160 5 Ni MH High 600–1200 5 220–250 5 42–110 5 210–365 5 Ni Cd High 1350 2 100 2 60 2 700 High-temperature Na batteries High 1000 5 150–280 8 80–120 1 315–490 8 LIB state of the art High 1000–6000 5 200–680 3 110–250 3 176 6 LIB energy-optimized Under Development 600–850 3 300-440 3 Classic Li Metal (CLIM) Under Development 800–1050 3 420–530 3 Metal Sulfur (Li S) Near Commercialization 100–500 5 350–680 3, 8 360–560 3, 8 36–130 5 Metal Sulfur (Na S) Under Development 5000–10,000 8 Metal Air (Li/air) Under Development 20–100 5 470–900 4 70–200 5 ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 6 IPCC WGIII AR6 Do Not Cite, Quote or Distribute 6-55 Total pages: 217 Metal Air (Zn/air) Under Development 150–450 5 200–410 4 70–160 5 Na ion Under Development 500 7 600 7 All-Solid-State Under Development 278–479 3 Redox Under Development >12,000– 14,000 10 15–2510 10–2010 6610 1 2 Drawbacks of batteries include relatively short lifespans and the use of hazardous or costly materials in 3 some variants. While LIB costs are decreasing (Schmidt et al. 2017; Vartiainen et al. 2020), the risk of 4 thermal runaway, which could ignite a fire (Gur 2018; Wang et al. 2019a), concerns about long-term 5 resource availability (Sun et al. 2017; Olivetti et al. 2017), and concerns about global cradle-to-grave 6 impacts (Peters et al. 2017; Kallitsis et al. 2020) need to be addressed. | Heritage | 997 - 998 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 29 CAES is a mature technology in use since the 1970s. Although CAES technologies have been 30 developed, there are not many installations at present (Blanc et al. 2020; Wang et al. 2017b). While the 31 opportunities for CAES are significant, with a global geological storage potential of about 6.5 PW 32 (Aghahosseini and Breyer 2018), a significant amount of initial investment is required. Higher 33 efficiencies and energy densities can be achieved by exploiting the hydrostatic pressure of deep water 34 to compress air within submersible reservoirs (Pimm et al. 2014). CAES is best suited to bulk diurnal 35 electricity storage for buffering VRE sources and services, which do not need a very rapid response. In 36 contrast to PHS, CAES has far more siting options and poses few environmental impacts. | Heritage | 998 - 998 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 7 Bulk Hydrogen Storage. Currently, hydrogen is stored in bulk in chemical processes such as metal and 8 chemical hydrides as well as in geologic caverns (Andersson and Grönkvist 2019; Caglayan et al. 2019) 9 (e.g., salt caverns operate in Sweden) (Elberry et al. 2021). There are still many challenges, however, 10 due to salt or hard rock geologies, large size, and minimum pressure requirements of the sites (IEA 11 2019c). Consequently, alternative carbon-free energy carriers, which store hydrogen, may become more 12 attractive (Kobayashi et al. 2019; Lan et al. 2012). | Heritage | 1005 - 1005 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 5 Other technologies that could expand the size of transmission corridors and/or improve the operational 6 characteristics include low-frequency AC transmission (LFAC) (Xiang et al. 2021; Tang et al. 2021b) 7 and half-wave AC transmission (HWACT) (Song et al. 2018; Xu et al. 2019). LFAC is technically 8 feasible, but the circumstances in which it is the best economic choice compared to HVDC or HVAC 9 still needs to be established (Xiang et al. 2016). HWACT is restricted to very long distances, and it has 10 not been demonstrated in practice, so its feasibility is unproven. There are still a number of 11 technological challenges for long-distance transmission networks such as protection systems for DC or 12 hybrid AC-DC networks (Franck C. et al. 2017; Chaffey 2016), improvement in cabling technology, 13 and including the use of superconductors and nanocomposites (Ballarino et al. 2016; Doukas 2019), 14 which require advanced solutions. | Heritage | 1006 - 1006 |

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| IPCC | IPCC_AR6_WGIII_Full_Report | 21 Contextual factors, such as physical and climate conditions, infrastructure, available technology, 22 regulations, institutions, culture, and financial conditions define the costs and benefits of mitigation 23 options that enable or inhibit their adoption (high confidence). Geographic location and climate factors 24 may make some technologies, such as solar PV or solar water heaters, impractical (Chang et al. 2009). | Heritage | 1007 - 1007 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 25 Culture can inhibit efficient use of home heating or PV (Sovacool and Griffiths 2020), low carbon diets 26 (Dubois et al. 2019), and advanced fuel choices (Van Der Kroon et al. 2013). Also, favourable financial 27 conditions promote the uptake of PV (Wolske and Stern 2018), good facilities increase recycling 28 (Geiger et al. 2019), and vegetarian meal sales increase when more vegetarian options are offered.. | Heritage | 1007 - 1007 |
| IPCC | IPCC_AR6_WGIII_Full_Report | Baseline New coal Existing coal New NGCC Existing NGCC Baseline emissions rate (tonCO2 MWh- 1 ) 0.8 0.9 0.34 0.42 LCOE (USD2020 kWh-1 ) 0.065 0.041 0.044 0.028 Utility scale solar PV (poor resource site) 0.100 44 USD tCO2- eq-1 66 USD tCO2- eq-1 165 USD tCO2- eq-1 171 USD tCO2- eq-1 Utility scale solar PV (good resource site) 0.035 –38 USD tCO2- eq-1 –7 USD tCO2- eq-1 –26 USD tCO2- eq-1 17 USD tCO2- eq-1 9 10 The feasibility and desirability of mitigation options extends well beyond the market economic costs of 11 installation and operation (Section 6.4.1). Figure 6.19 summarizes the barriers and enablers for 12 implementing different mitigation options in energy systems. The feasibility of different options can be 13 enhanced by removing barriers and/or strengthening enablers of the implementation of the options. The 14 feasibility of options may differ across context (e.g., region), time (e.g., 2030 versus 2050), scale (e.g., 15 small versus large) and the long-term warming goal (e.g., 1.5°C versus 2°C). | Heritage | 1010 - 1010 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 15 ● Culture can encompass the articulation of positive discourses, narratives, and visions that enhance 16 cultural legitimacy and societal acceptance of new technologies. Regulatory embedding can capture 17 the variety of policies that shape production, markets and use of new technologies. | Heritage | 1056 - 1056 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 26 7.3.1.5. Logging and fuelwood harvest 27 The area of forest designated for production has been relatively stable since 1990. Considering forest 28 uses, about 30% (1.2 billion ha) of all forests is used primarily for production (wood and non-wood 29 forest products), about 10% (424 Mha) is designated for biodiversity conservation, 398 Mha for the 30 protection of soil and water, and 186 Mha is allocated for social services (recreation, tourism, education 31 research and the conservation of cultural and spiritual sites) (FAO and UNEP 2020). While the rate of 32 increase in the area of forest allocated primarily for biodiversity conservation has slowed in the last ten 33 years, the rate of increase in the area of forest allocated for soil and water protection has grown since 34 1990, and notably in the last ten years. Global wood harvest (including from forests, other wooded land and trees outside forests) was estimated to be almost 4.0 billion m3 35 in 2018 (considering both industrial 36 roundwood and fuelwood) (FAO, 2019). Overall, wood removals are increasing globally as demand 37 for, and the consumption of wood products grows annually by 1% in line with growing populations and 38 incomes with this trend expected to continue in coming decades. When done in a sustainable way, more 39 regrowth will occur and is stimulated by management, resulting in a net sink. However illegal and 40 unsustainable logging (i.e. harvesting of timber in contravention of the laws and regulations of the 41 country of harvest) is a global problem with significant negative economic (e.g. lost revenue), 42 environmental (e.g. deforestation, forest degradation, GHG emissions and biodiversity losses) and 43 social impact (e.g. conflicts over land and resources, disempowerment of local and indigenous 44 communities) (World Bank 2019). Many countries around the world have introduced regulations for 45 the international trade of forest products to reduce illegal logging, with significant and positive impacts 46 (Guan et al. 2018). | Heritage | 1193 - 1193 |
| IPCC | IPCC_AR6_WGIII_Full_Report | Science and technology Technological factors operates in conjunction with economic drivers of land use and management, whether through intensified farming techniques and biotechnology, high-input approaches to rehabilitating degraded land (e.g. Lin et al. 2017; Guo et al. 2020) or through new forms of data collection and monitoring (e.g. Song et al. 2018; Thyagharajan and Vignesh 2019; Arévalo et al. 2020). | Heritage | 1197 - 1197 |
| IPCC | IPCC_AR6_WGIII_Full_Report | Research and development are central to forest restoration strategies that have become increasingly important around the world as costs vary depending on methods used, from natural regeneration with native tree species to active restoration using site preparation and planting (Lőf et al. 2019). | Heritage | 1197 - 1197 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 5 Key uncertainties remain in mapping extent and conversion rates for salt marshes and seagrasses (McKenzie et al. 2020). Seagrass loss rates were estimated at 1-2% y-1 6 (Dunic et al. 2021) with 7 stabilization in some regions (IPCC WGII Ch. 3.4.2.5; (de los Santos et al. 2019); however, loss occurs 8 non-linearly and depends on site-specific context. Tidal marsh extent and conversion rates remains 9 poorly estimated, outside of the USA, Europe, South Africa, and Australia (Mcowen et al. 2017; 10 Macreadie et al. 2019). | Heritage | 1220 - 1220 |

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| IPCC | IPCC_AR6_WGIII_Full_Report | 18 7.4.2.9. Coastal wetland restoration 19 Activities, co-benefits, risks and implementation barriers. Coastal wetland restoration involves 20 restoring degraded or damaged coastal wetlands including mangroves, salt marshes, and seagrass 21 ecosystems, leading to sequestration of 'blue carbon' in wetland vegetation and soil (SRCCL Ch 6, 22 SROCCC Ch 5). Successful approaches to wetland restoration include: (1) passive restoration, the 23 removal of anthropogenic activities that are causing degradation or preventing recovery; and (2) active 24 restoration, purposeful manipulations to the environment in order to achieve recovery to a naturally 25 functioning system (Elliott et al. 2016; IPCC WGII Ch 3). Restoration of coastal wetlands delivers 26 many valuable co-benefits, including enhanced water quality, biodiversity, aesthetic values, fisheries 27 production (food security), and protection from rising sea levels and storm impacts (Barbier et al. 2011; Hochard et al. 2019; Sun and Carson 2020; Duarte et al. 2020). Of the 0.3 Mkm2 28 coastal wetlands globally, 0.11 Mkm2 29 of mangroves are considered feasible for restoration (Griscom et al. 2017). Risks 30 associated with coastal wetland restoration include uncertain permanence under future climate scenarios 31 (IPCC WGII AR6 Box 3.4), partial offsets of mitigation through enhanced methane and nitrous oxide 32 release and carbonate formation, and competition with other land uses, including aquaculture and 33 human settlement and development in the coastal zone (SROCCC, Chapter 5). To date, many coastal 34 wetland restoration efforts do not succeed due to failure to address the drivers of degradation (van 35 Katwijk et al. 2016). However, improved frameworks for implementing and assessing coastal wetland 36 restoration are emerging that emphasize the recovery of ecosystem functions (Cadier et al. 2020; Zhao 37 et al. 2016). Restoration projects that involve local communities at all stages and consider both 38 biophysical and socio-political context are more likely to succeed (Brown et al. 2014; Wylie et al. 2016). | Heritage | 1220 - 1220 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 27 There is high site-specific variation in carbon sequestration rates and uncertainties regarding the 28 response to future climate change (Jennerjahn et al. 2017; Nowicki et al. 2017; IPCC WGII AR6 Box 29 3.4). Changes in distributions (Kelleway et al. 2017; Wilson and Lotze 2019), methane release (Al-Haj 30 and Fulweiler 2020), carbonate formation (Saderne et al. 2019), and ecosystem responses to interactive 31 climate stressors are not well-understood (Short et al. 2016; Fitzgerald and Hughes 2019; Lovelock and 32 Reef 2020). | Heritage | 1221 - 1221 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 23 2016). Besides CDR, additional mitigation can arise from displacing fossil fuels with pyrolysis gases, 24 lower soil N2O emissions (Cayuela et al. 2014, 2015; Song et al. 2016; He et al. 2017; Verhoeven et al. | Heritage | 1223 - 1223 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 25 2017; Borchard et al. 2019), reduced nitrogen fertiliser requirements due to reduced nitrogen leaching 26 and volatilisation from soils (Liu et al. 2019; Borchard et al. 2019), and reduced GHG emissions from 27 compost when biochar is added (Agyarko-Mintah et al. 2017; Wu et al. 2017). Biochar application to 28 paddy rice has resulted in substantial reductions (20-40% on average) in N2O (Awad et al. 2018; Liu et 29 al. 2018; Song et al. 2016) (Section 7.4.3.5) and smaller reduction in CH4 emissions (Kammann et al. | Heritage | 1223 - 1223 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 30 2017; Kim et al. 2017a; Song et al. 2016; He et al. 2017; Awad et al. 2018). Potential co-benefits include 31 yield increases particularly in sandy and acidic soils with low cation exchange capacity (Woolf et al. | Heritage | 1223 - 1223 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 7 2018; Gao et al. 2020) and reduced GHG and ammonia emissions from compost and manure (Sanchez- 8 Monedero et al. 2018; Bora et al. 2020a,b; Zhao et al. 2020). A quantification method based on biochar 9 properties is included in the IPCC guidelines for NGHGIs (IPCC 2019b). Studies report a range of 10 biochar responses, from positive to occasionally adverse impacts, including on GHG emissions, and 11 identify risks (Tisserant and Cherubini 2019). This illustrates the expected variability (Lehmann and 12 Rillig 2014) of responses, which depend on the biochar type and climatic and edaphic characteristics of 13 the site (Zygourakis 2017). Biochar properties vary with feedstock, production conditions and post- 14 production treatments, so mitigation and agronomic benefits are maximised when biochars are chosen 15 to suit the application context (Mašek et al. 2018). A recent assessment finds greatest economic potential (up to USD100 tCO2 -1 16 ) between 2020 and 2050 to be in Asia and the developing Pacific (793 MtCO2 yr-1 ) followed by Developed Countries (447 MtCO2 yr-1 17 ) (Roe et al. 2021). Mitigation through biochar 18 will be greatest where biochar is applied to responsive soils (acidic, low fertility), where soil N2O 19 emissions are high (intensive horticulture, irrigated crops), and where the syngas co-product displaces 20 fossil fuels. Due to the early stage of commercialisation, mitigation estimates are based pilot-scale 21 facilities, leading to uncertainty. However, the long-term persistence of biochar carbon in soils has been 22 widely studied (e.g. Singh et al. 2012; Fang et al. 2019; Zimmerman and Ouyang 2019). The greatest 23 uncertainty is the availability of sustainably-sourced biomass for biochar production. | Heritage | 1224 - 1224 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 42 Barriers to adoption may include site-specific limitations regarding soil type, percolation and seepage 43 rates or fluctuations in precipitation, water canal or irrigation infrastructure, paddy surface level and 44 rice field size, and social factors including farmer perceptions, pump ownership, and challenges in 45 synchronising water management between neighbours and pumping stations (Yamaguchi et al. 2019; 46 Yamaguchi et al. 2017; Quynh and Sander 2015). | Heritage | 1228 - 1228 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 9 Developments since AR5 and IPCC Special Reports (SR1.5, SROCCC and SRCCL). Since AR5 and 10 the SRCCL, studies on mitigation have principally focused on water and nutrient management practices 11 with the aim of improving overall sustainability as well as measurements of site-specific emissions to 12 help improve the resolution of regional estimates. Intensity of emissions show considerable spatial and 13 temporal variation, dependent on site specific factors including degradation of soil organic matter, 14 management of water levels in the field, the types and amount of fertilisers applied, rice variety and local cultivation practices. Variation in CH4 emissions have been found to range from 0.5-41.8 mg/m2 15 /hr 16 in Southeast Asia (Sander et al. 2014; Chidthaisong et al. 2018; Setyanto et al. 2018; Sibayan et al. | Heritage | 1229 - 1229 |

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| IPCC | IPCC_AR6_WGIII_Full_Report | 27 2018). Water management for both single and multiple drainage can (most likely) reduce methane 28 emissions by ~35 % but increase N2O emissions by about 20% (Yagi et al. 2020). However, N2O 29 emissions occur only under dry conditions, therefore total reduction in terms of net GWP is 30 approximately 30%. Emissions of N2O are higher during dry seasons (Yagi et al. 2020) and depend on 31 site specific factors as well as the quantity of fertiliser and organic matter inputs into the paddy rice 32 system. Variability of N2O emissions from single and multiple drainage can range from 0.06-33 kg/ha 33 (Hussain et al. 2015; Kritee et al. 2018). AWD in Vietnam was found to reduce both CH4 and N2O 34 emissions by 29-30 and 26-27% respectively with the combination of net GWP about 30% as compared 35 to continuous flooding (Tran et al. 2018). Overall, greatest average economic mitigation potential (up to USD100 tCO2-eq-1 36 ) between 2020 and 2050 is estimated to be in Asia and the developing Pacific (147.2 MtCO2-eq yr-1 ) followed by Latin America and the Caribbean (8.9 MtCO2-eq yr-1 37 ) using the 38 IPCC AR4 GWP100 value for CH4 (Roe et al. 2021). | Heritage | 1229 - 1229 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 39 Critical assessment and conclusion. There is medium confidence that improved rice management has a technical potential of 0.3 (0.1-0.8) GtCO2-eq yr-1 40 between 2020 and 2050, of which 0.2 (0.05-0.3) GtCO2-eq yr-1 is available up to USD100 tCO2-eq-1 41 (Figure 7.11). Improving rice cultivation practices 42 will not only reduce GHG emissions, but also improve production sustainability in terms of resource 43 utilisation including water consumption and fertiliser application. However, emission reductions show 44 high variability and are dependent on site specific conditions and cultivation practices. | Heritage | 1229 - 1229 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 33 Interactions and limitations 34 The integration of technologies and services that are suitable for the local conditions resulted in many 35 gains for food security and adaptation and for mitigation where appropriate. It was also shown that, in 36 all regions, there is considerable yield advantage when a portfolio of technologies is used, rather than 37 the isolated use of technologies (Govaerts et al. 2005; Zougmoré et al. 2014). Moreover, farmers are 38 using research results to promote their products as climate-smart leading to increases in their income 39 (Acosta-Alba et al. 2019). However, climatic risk sites and socioeconomic conditions together with a 40 lack of resource availability are key issues constraining agriculture across all five regions. | Heritage | 1231 - 1231 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 25 While expectations that carbon-centred REDD+ would be a simple and efficient mechanism for climate 26 mitigation have not been met (Turnhout et al. 2017; Arts et al. 2019), progress has nonetheless occurred. | Heritage | 1260 - 1260 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 24 Identified lessons - The elements of sustainability are intertwined with Menominee history, culture, 25 spirituality, and ethics. The balance between the environment, community, and economy for the short 26 term as well as future generations is an example of protecting the entire environment as the Menominee 27 land is a non-fragmented remnant of the prehistoric Lake States forest which has been dramatically 28 reduced all around the reserve (Schabel and Pecore 1997). These and other types of community forest 29 owner associations exist all over the world. Examples are Södra in Sweden (with 52,000 forest owners) 30 (Södra, 2021) or Waldbauernverband in North-Rhine Westphalia (with 150,000 forest owners and 31 covering 585,000 ha) (AGDW-The Forest Owners, 2021). These are ways for small forest owners 32 to educate, jointly put wood on the market, employ better forest management, use machinery together, 33 and apply certification jointly. In this manner and with all their diversity of goals, they manage to 34 maintain carbon sinks and stocks, while preserving biodiversity and producing wood. | Heritage | 1263 - 1263 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 42 Permanence focuses on the potential for carbon sequestered in offsets to be released in the future due 43 to natural or anthropogenic disturbances. Most offset registries have strong permanence requirements, 44 although they vary in their specific requirements. VCS/Verra requires a pool of additional carbon credits 45 that provides a buffer against inadvertent losses. The Climate Action Reserve (CAR) protocol for forests ACCEPTED VERSION SUBJECT TO FINAL EDITS Final Government Distribution Chapter 7 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 7-108 Total pages: 185 1 requires carbon to remain on the site for 100 years. The carbon on the site will be verified at pre- 2 determined intervals over the life of the project. If carbon is diminished on a given site, the credits for 3 the site have to be relinquished and the project developer has to use credits from their reserve fund 4 (either other projects or purchased credits) to make up for the loss. Estimates of leakage in forestry 5 projects in the AR5 suggest that it can range from 10% to over 90% in the USA (Murray et al. 2004), 6 and 20-50% in the tropics (Sohngen and Brown 2004) for forest set-asides and reduced harvesting. | Heritage | 1267 - 1268 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 7 Financing needs in AFOLU, and in particular in forestry, include both the direct effects of any changes 8 in activities – costs of planting or managing trees, net revenues from harvesting, costs of thinning, costs 9 of fire management, etc. – as well as the opportunity costs associated with land use change. Opportunity 10 costs are a critical component of AFOLU finance, and must be included in any estimate of the funds 11 necessary to carry out projects. They are largest, as share of total costs, in forestry because they play a 12 prominent role in achieving high levels of afforestation, avoided deforestation, and improved forest 13 management. In case of increasing soil carbon in croplands through reduced tillage, there are often cost 14 savings associated with increased residues because there is less effort tilling, but the carbon effects per 15 hectare are also modest. There could, however, be small opportunity costs in cases where residues may 16 otherwise be marketed to a biorefinery. The effect of reduced tillage on yields varies considerably across 17 sites and crop types, but tends to enhance yields modestly in the longer-run. | Heritage | 1273 - 1273 |

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| IPCC | IPCC_AR6_WGIII_Full_Report | 37 Cultural values and social acceptance. Barriers to adoption of AFOLU mitigation will be strongest 38 where historical practices represent long-standing traditions (high confidence). Adoption of new 39 mitigation practices, however, may proceed quickly if the technologies can be shown to improve crop 40 yields, reduce costs, or otherwise improve livelihoods (Ranjan 2019). AR6 presents new estimates of 41 the mitigation potential for shifts in diets and reductions in food waste, but given long-standing dietary 42 traditions within most cultures, some of the strongest barriers exist for efforts to change diets (medium 43 confidence). Furthermore, the large number of undernourished who may benefit from increased calories 44 and meat will complicate efforts to change diets. Regulatory or tax approaches will face strong 45 resistance, while efforts to use educational approaches and voluntary measures have limited potential 46 to slow changes in consumption patterns due to free-riders, rebound effects, and other limitations. Food ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 7 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 7-114 Total pages: 185 1 loss and waste occurs across the supply chain, creating significant challenges to reduce it (FAO 2019c). | Heritage | 1273 - 1274 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 9 Implementation of nature-based solution may have local or regionally important consequences for other 10 ecosystem services, some of which may be negative (high confidence). Land use change has important 11 implications for the hydrological cycle, and the large land use shifts suggested for BECCS when not 12 carried out in a carefully planned manner, are expected to increase water demands substantially across 13 the globe (Stenzel et al. 2019; Rosa et al. 2020). Afforestation can have minor to severe consequences 14 for surface water acidification, depending on site-specific factors and exposure to air pollution and sea-15 salts (Futter et al. 2019). The potential effects of coastal afforestation on sea-salt related acidification 16 could lead to re-acidification and damage on aquatic biota. | Heritage | 1275 - 1275 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 17 Specific soil conditions, water availability, GHG emission-reduction potential as well as natural 18 variability and resilience. Recent analysis by (Cook-Patton et al. 2020) illustrates large variability in 19 potential rates of carbon accumulation for afforestation and reforestation options, both within 20 biomes/ecozones and across them. Their results suggest that while there is large potential for 21 afforestation and reforestation, the carbon uptake potential in land-based climate change mitigation 22 efforts is highly dependent on the assumptions related to climate drivers, land use and land management, 23 and soil carbon responses to land-use change. Less analysis has been conducted on bioenergy crop 24 yields, however, bioenergy crop yields are also likely to be highly variable, suggesting that bioenergy 25 supply could exceed or fall short of expectations in a given region, depending on site conditions. | Heritage | 1275 - 1275 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 22 7.6.4.4. Technological barriers and opportunities 23 Monitoring, reporting, and verification. Development of satellite technologies to assess potential 24 deforestation has grown in recent years with the release of 30 m data by Hansen et al. (2013), however, 25 this data only captures tree cover loss, and increasing accuracy over time may limit its use for trend 26 analysis (Ceccherini et al. 2020; Palahí et al. 2021). Datasets on forest losses are less well developed 27 for reforestation and afforestation. As Mitchell et al. (2017) point out, there has been significant 28 improvement in the ability to measure changes in tree and carbon density on sites using satellite data, 29 but these techniques are still evolving and improving and they are not yet available for widespread use. | Heritage | 1276 - 1276 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 36 Although numerous studies have estimated the value of ecosystem services for different sites, 37 ecosystems, and regions, these studies mostly evaluate ecosystem services at a single point in time See 38 (Costanza et al. 1997; Nahuelhual et al. 2007; de Groot et al. 2012; Ninan and Kontoleon 2016; Xue 39 and Tisdell 2001). The few studies that have assessed the trends in the value of ecosystem services 40 provided by different ecosystems across regions and countries indicate a declining trend (Costanza et 41 al. 2014; Kubiszewski et al. 2017). Land use change is a major driver behind loss of biodiversity and 42 ecosystem services in most regions (Archer et al. 2018; Rice et al. 2018; IPBES 2018b; M. Fischer et 43 al. 2018). Projected impacts of land use change and climate change on biodiversity and ecosystem 44 services (material and regulating services) between 2015 to 2050 were assessed to have relatively less 45 negative impacts under global sustainability scenarios as compared to regional competition and 46 economic optimism scenarios (Díaz et al. 2019). The projected impacts were based on a subset of 47 Shared Socioeconomic Pathway (SSP) scenarios and GHG emissions trajectories (RCP) developed in ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 7 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 7-119 Total pages: 185 1 support of IPCC assessments. There are synergies, trade-offs and co-benefits between ecosystem 2 services and mitigation options with impacts on ecosystem services differing by scale and contexts 3 (high confidence). Measures such as conservation agriculture, agroforestry, soil and water conservation, 4 afforestation, adoption of silvopastoral systems, can help minimise trade-offs between mitigations 5 options and ecosystem services (Duguma et al. 2014). Climate smart agriculture (CSA) is being 6 promoted to enable farmers to make agriculture more sustainable and adapt to climate change (Box 7 7.4). However, experience with CSA in Africa has not been encouraging. For instance, a study of 8 climate smart cocoa production in Ghana shows that due to lack of tenure (tree) rights, bureaucratic and 9 legal hurdles in registering trees in cocoa farms, and other barriers small cocoa producers could not 10 realise the project benefits (Box 7.13). Experience of CSA in some other Sub-Saharan African countries 11 and other countries such as Belize too has been constrained by weak extension systems and policy 12 implementation, and other barriers (Arakelyan et al. 2017; Kongsager 2017). | Heritage | 1278 - 1279 |

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| Organisation | Document | Quotation Content | Codes | Page |
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| IPCC | IPCC_AR6_WGIII_Full_Report | 40 While appearing to create a net removal of carbon from the atmosphere, BECCS requires land, water 41 and energy which can create adverse side-effects at scale. Controversy has arisen because some of the 42 models calculating the energy mix required to keep the temperature to 1.5°C have included BECCS at 43 very large scales as a means of both providing energy and removing carbon from the atmosphere to 44 offset emissions from industry, power, transport or heat. For example, studies have calculated that for 45 BECCS to achieve 11.5 GtCO2-eq per year of carbon removal in 2100, as envisaged in one scenario, 46 380-700 Mha or 25-46% of all the world's arable and cropland would be needed. In such a situation, ACCEPTED VERSION SUBJECT TO FINAL EDITS Final Government Distribution Chapter 7 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 7-124 Total pages: 185 1 competition for agricultural land seriously threatens food production and food security, while also 2 impacting biodiversity, water and soil quality, and landscape aesthetic value. More recently however, 3 the scenarios for BECCS have become much more realistic, though concerns regarding impacts on food 4 security and the environment remain, while the reliability of models is uncertain due to methodological 5 flaws. Improvements to models are required to better capture wider environmental and social impacts 6 of BECCS in order to ascertain its sustainable contribution in emissions pathways. Additionally, the 7 opportunity for other options that could negate very large-scale deployment of BECCS, such as other 8 carbon dioxide removal measures or more stringent emission reductions in other sectors, could be 9 explored within models. | Heritage | 1283 - 1284 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 7 These mitigation potentials depend on numerous factors and the scale of implementation. The 8 temperature reduction potential for green roofs when compared to conventional roofs can be about 4°C 9 in winter and about 12°C during summer conditions (Bevilacqua et al. 2016). Green roofs can reduce 10 building heating demands by about 10–30% compared to conventional roofs (Besir and Cuce 2018), 11 60–70% compared to black roofs, and 45–60% compared to white roofs (Silva et al. 2016). Green walls 12 or facades can provide a temperature difference between air temperature outside and behind a green 13 wall of up to 10°C, with an average difference of 5°C in Mediterranean contexts in Europe (Perini et 14 al. 2017). The potential of saving energy for air conditioning by green facades can be around 26% in 15 summer months. Considerations of the spatial context are essential given their dependence on climatic 16 conditions (Susca 2019). Cities are diverse and emissions savings potentials depend on several factors, 17 while the implementation of green roofs or facades may be prevented in heritage structures. | Heritage | 1415 - 1415 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 11 Cities where urban infrastructure has already been built have opportunities to increase energy efficiency 12 measures, prioritize compact and mixed-use neighbourhoods through urban regeneration, advance the 13 urban energy system through electrification, undertake cross-sector synergies, integrate urban green and 14 blue infrastructure, encourage behavioural and lifestyle change to reinforce climate mitigation, and put 15 into place a wide range of enabling conditions as necessary to guide and coordinate actions in the urban 16 system and its impacts in the global system. Retrofitting buildings with state of the art deep energy 17 retrofit measures could reduce emissions of the existing stock by about 30–60% (Creutzig et al. 2016a) 18 and in some cases up to 80% (Ürge-Vorsatz et al. 2020) (see Section 8.4.3). | Heritage | 1434 - 1434 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 48 ACCEPTED VERSION SUBJECT TO FINAL EDITS Final Government Distribution Chapter 9 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 9-7 Total pages: 168 1 9.1 Introduction 2 Total GHG emissions in the building sector reached 12 GtCO2eq. in 2019, equivalent to 21% of global 3 GHG emissions that year, of which 57% were indirect CO2 emissions from offsite generation of 4 electricity and heat, followed by 24% of direct CO2 emissions produced on-site and 18% from the 5 production of cement and steel used for construction and/or refurbishment of buildings. If only CO2 6 emissions would be considered, the share of buildings CO2 emissions increases to 31% out of global 7 CO2 emissions. Energy use in residential and non-residential buildings contributed 50% and 32% 8 respectfully, while embodied emissions contributed 18% to global building CO2 emissions. Global final 9 energy demand from buildings reached 128.8 EJ in 2019, equivalent to 31% of global final energy 10 demand. Residential buildings consumed 70% out of global final energy demand from buildings. | Heritage | 1508 - 1509 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 11 Non-residential buildings have a much broader use. They include cultural buildings (which include 12 theatres and performance, museums and exhibits, libraries, and cultural centres), educational buildings 13 (kindergarten, schools, higher education, research centre, and laboratories), sports (recreation and 14 training, and stadiums), healthcare buildings (health, wellbeing, and veterinary), hospitality (hotel, 15 casino, lodging, nightlife buildings, and restaurants and bars), commercial buildings and offices 16 (institutional buildings, markets, office buildings, retail, and shopping centres), public buildings 17 (government buildings, security, and military buildings), religious buildings (including worship and 18 burial buildings), and industrial buildings (factories, energy plants, warehouses, data centres, 19 transportation buildings, and agricultural buildings). | Heritage | 1513 - 1513 |

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| Organisation | Document | Quotation Content | Codes | Page |
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| IPCC | IPCC_AR6_WGIII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS Final Government Distribution Chapter 9 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 9-12 Total pages: 168 1 2 Figure 9.1 The main building components 3 ACCEPTED VERSION SUBJECT TO FINAL EDITS Final Government Distribution Chapter 9 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 9-13 Total pages: 168 1 At a global level, from historical perspective (from the Neolithic to the present), building techniques 2 have evolved to be able to solve increasingly complex problems. Vernacular architecture has evolved 3 over many years to address problems inherent in housing. Through a process of trial and error, 4 populations have found ways to cope with the extremes of the weather. The industrial revolution was 5 the single most important development in human history over the past three centuries. Previously, 6 building materials were restricted to a few manmade materials (lime mortar and concrete) along with 7 those available in nature as timber and stone. Metals were not available in sufficient quantity or 8 consistent quality to be used as anything more than ornamentation. The structure was limited by the 9 capabilities of natural materials; this construction method is called on-site construction which all the 10 work is done sequentially at the buildings site. The Industrial Revolution changed this situation 11 dramatically, new building materials emerged (cast-iron, glass structures, steel-reinforced concrete, 12 steel). Iron, steel and concrete were the most important materials of the nineteenth century (De 13 Villanueva Domínguez 2005; Wright 2000). In that context, prefabricated buildings (prefabrication also 14 known as pre-assembly or modularization) appeared within the so-called off-site construction. | Heritage | 1513 - 1515 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 15 Prefabrication has come to mean a method of construction whereby building elements and materials, 16 ranging in size from a single component to a complete building, are manufactured at a distance from 17 the final building location. Prefabricated buildings have been developed rapidly since World War II and 18 are widely used all over the world (Pons 2014; Moradibistouni et al. 2018) 19 Recently, advances in technology have produced new expectations in terms of design possibilities. In 20 that context, 3D printing seems to have arrived. 3D printing may allow in the future to build faster, 21 cheaper and more sustainable (Agustí-Juan et al. 2017; García de Soto et al. 2018). At the same time, it 22 might introduce new aesthetics, new materials, and complex shapes that will be printed at the click of 23 a mouse on our computers. Although 3D printing will not replace architectural construction, it would 24 allow optimization of various production and assembly processes by introducing new sustainable 25 construction processes and tools (De Schutter et al. 2018). Nevertheless, what is clear is that 3D printing 26 is a technology still in development, with a lot of potentials and that it is advancing quite quickly (Hager 27 et al. 2016; Stute et al. 2018; Wang et al. 2020). | Heritage | 1515 - 1515 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 28 29 9.3 New developments in emission trends and drivers 30 9.3.1 Past and future emission trends 31 Total GHG emissions in the building sector reached 12 GtCO2eq. in 2019, equivalent to 21% of global 32 GHG emissions that year. 57% of GHG emissions from buildings were indirect CO2 emissions from 33 generation of electricity and heat off-site, 24% were direct CO2 emissions produced on-site, and 18% 34 were from the production of cement and steel used for construction and refurbishment of buildings 35 (Figure 9.3a) (see Cross-Chapter Box 3 and Cross-Working Group Box 1 in Chapter 3). Halocarbon 36 emissions were equivalent to 3% of global building GHG emissions in 2019. In the absence of the 37 breakdown of halocarbon emissions per end-use sectors, they have been calculated for the purpose of 38 this chapter, by considering that 60% of global halocarbon emissions occur in buildings (Hu et al. 2020). | Heritage | 1517 - 1517 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 5 The literature evaluating the embodied energy in building materials is extensive, but that considering 6 embodied carbon is much more scarce (Cabeza et al. 2021). Recently this evaluation is done using the 7 methodology life cycle assessment (LCA), but since the boundaries used in those studies are different, 8 varying for example, in the consideration of cradle to grave, cradle to gate, or cradle to cradle, the 9 comparison is very difficult (Moncaster et al. 2019). A summary of the embodied energy and embodied 10 carbon cradle to gate coefficients reported in the literature are found in Figure 9.9 (Alcorn and Wood 11 1998; Birgisdottir et al. 2017; Cabeza et al. 2013; De Wolf et al. 2016; Symons 2011; Moncaster and 12 Song 2012; Omrany et al. 2020; Pomponi and Moncaster 2016, 2018; Crawford and Treolar 2010; 13 Vukotic et al. 2010; Cabeza et al. 2021). Steel represents the materials with higher embodied energy, 32-35 MJ·kg-1 14 ; embodied energy in masonry is higher than in concrete and earth materials, but 15 surprisingly, some type of wood have more embodied energy than expected; there are dispersion values 16 in the literature depending of the ma. On the other hand, earth materials and wood have the lowest 17 embodied carbon, with less than 0.01 kg CO2 per kg of material (Cabeza et al. 2021). The concept of 18 buildings as carbon sinks raise from the idea that wood stores considerable quantities of carbon with a 19 relatively small ratio of carbon emissions to material volume and concrete has substantial embodied 20 carbon emissions with minimal carbon storage capacity (Churkina et al. 2020; Sanjuán et al. 2019). | Heritage | 1535 - 1535 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 15 9.4.4.2 Historical and heritage buildings 16 Historical buildings, defined as those built before 1945, are usually low-performance buildings by 17 definition from the space heating point of view and represent almost 30–40% of the whole building 18 stock in European countries (Cabeza et al. 2018a). Historical buildings often contribute to townscape 19 character, they create the urban spaces that are enjoyed by residents and attract tourist visitors. They 20 may be protected by law from alteration not only limited to their visual appearance preservation, but 21 also concerning materials and construction techniques to be integrated into original architectures. On 22 the other hand, a heritage building is a historical building which, for their immense value, is subject to 23 legal preservation. The integration of renewable energy systems in such buildings is more challenging 24 than in other buildings. The review carried out by (Cabeza et al. 2018a) different case studies are 25 presented and discussed, where heat pumps, solar energy and geothermal energy systems are integrated 26 in such buildings, after energy efficiency is considered. | Heritage | 1545 - 1545 |

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| Organisation | Document | Quotation Content | Codes | Page |
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| IPCC | IPCC_AR6_WGIII_Full_ Report | 27 9.4.4.3 Positive energy or energy plus buildings 28 The integration of energy generation on-site means further contribution of buildings towards 29 decarbonisation (Ürge-Vorsatz et al. 2020). Integration of renewables in buildings should always come 30 after maximising the reduction in the demand for energy services through sufficiency measures and 31 maximising efficiency improvement to reduce energy consumption, but the inclusion of energy 32 generation would mean a step forward to distributed energy systems with high contribution from 33 buildings, becoming prosumers (Sánchez Ramos et al. 2019). Decrease price of technologies such as 34 PV and the integration of energy storage (de Gracia and Cabeza 2015) are essential to achieve this 35 objective. Other technologies that could be used are photovoltaic/thermal (Sultan and Ervina Efzan 36 2018), solar/biomass hybrid systems (Zhang et al. 2020b), solar thermoelectric (Sarbu and Dorca 2018), 37 solar powered sorption systems for cooling (Shirazi et al. 2018), and on-site renewables with battery 38 storage (Liu et al. 2021). | Heritage | 1545 - 1545 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | 16 9.5.2.5 Value-chain, social and institutional innovations 17 Cooperative efforts are necessary to improve buildings energy efficiency (Masuda and Claridge 2014; 18 Kamilaris et al. 2014; Ruparathna et al. 2016). For instance, inter-disciplinary understanding of 19 organizational culture, occupant behaviour, and technology adoption is required to set up 20 occupancy/operation best practises (Janda 2014). Similarly, close collaboration of all actors along the 21 value chain can reduce by 50% emissions from concrete use (Habert et al. 2020); such collaboration 22 can be enhanced in a construction project by transforming the project organisation and delivery contract 23 to reduce costs and environmental impact (Hall and Bonanomi 2021). Building commissioning helps to 24 reduce energy consumption by streamlining the systems, but benefits may not persistent. Energy 25 communities are discussed later in the chapter. | Heritage | 1552 - 1552 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 9 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 9-51 Total pages: 168 1 Table 9.3 Reasons for adoption of climate mitigation solutions. The sign represents if the effect is positive 2 (+) or negative (-), and the number of signs represents confidence level (++, many references; +, few 3 references) (Mata et al. 2021a) Climate mitigation solutions for buildings Building envelope Efficient technical systems On-site renewable energy Behaviour Performance standards Low-carbon materials Digitalization and flexibility Circular and sharing econ. | Heritage | 1552 - 1553 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | 8 Motivations are often triggered by urgent comfort or replacement needs. Maintaining the aesthetic value 9 may as well hinder the installation of insulation if no technical solutions are easily available (Haines 10 and Mitchell 2014; Bright et al. 2019). Local professionals and practitioners can both encourage 11 (Ozarisoy and Altan 2017; Friege 2016) and discourage the installation of insulation, according to their 12 knowledge and training (Maxwell et al. 2018; Curtis et al. 2017; Zuhaib et al. 2017; Tsoka et al. 2018). | Heritage | 1554 - 1554 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | 4 Government support is needed an initiator but also to reinforce building retrofft targets, promote more 5 stringent energy and material standards for new constructions, and protect consumer interests 6 (Hongping 2017; Fischer and Pascucci 2017; Patwa et al. 2020). Taxes clearly incentivize waste 7 reduction and recycling (Ajayi et al. 2015; Rachel and Travis 2011; Volk et al. 2019). In developing 8 countries, broader, international, market boundaries can allow for a more attractive business model 9 (Mohit et al. 2020). Participative and new ownership models can favour the adoption of prefabricated 10 buildings (Steinhardt and Manley 2016). Needs for improvements are observed, in terms of design for 11 flexibility and deconstruction, procurement and prefabrication and off-site construction, standardization 12 and dimensional coordination, with differences among solutions (Ajayi et al. 2017)(Schiller et al, 13 2015,2017; Osmani, 2012; Lu and Yuan, 2013; Cossu and Williams, 2015; Bakshan et al 2017; Coehlo 14 et al 2013). | Heritage | 1556 - 1556 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | 15 Although training is a basic requirement, attitude, past experience, and social pressure can also be highly 16 relevant, as illustrated for waste management in a survey to construction site workers (Amal et al. 2017). | Heritage | 1556 - 1556 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | 17 Traditional community practices of reuse of building elements are observed to be replaced by a culture 18 of waste (Hongping 2017; Ajayi et al. 2015). | Heritage | 1556 - 1556 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | 25 Changes in cloud formation can affect global solar irradiation and, therefore, the output of solar 26 photovoltaic panels, possibly affecting on-site renewable energy production (Burnett et al. 2014). The 27 efficiency of solar photovoltaic panels and their electrical components decreases with higher 28 temperatures (Simioni and Schaeffer 2019) (Bahaidarah et al. 2013). However, studies have found that 29 such effect can be relatively small (Totschnig et al. 2017), making solar PV a robust option to adapt to 30 climate change (Shen and Lior 2016; Santos and Lucena 2021) (see Section 9.4). | Heritage | 1568 - 1568 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | 25 2020) (see Section 9.4, Figure 9.11 and Tables SM9.1 to SM9.3). This can also be achieved with on- 26 site renewable energy production, especially solar PV for which there can be a timely correlation 27 between power supply and cooling demand, improving load matching (Salom et al. 2014; Grove-Smith 28 et al. 2018). | Heritage | 1569 - 1569 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | 26 Also, energy efficiency, sufficiency and on-site renewable energy production can help to increase 27 building resilience to climate change impacts and reduce pressure on the energy system. | Heritage | 1570 - 1570 |

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| Organisation | Document | Quotation Content | Codes | Page |
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| IPCC | IPCC_AR6_WGIII_Full_Report | 44 45 9.9 Sectoral barriers and policies 46 9.9.1 Barriers, feasibility, and acceptance 47 Understanding the reasons why cost-effective investment in building energy efficiency are not taking 48 place as expected by rational economic behaviour is critical to design effective policies for decarbonize 49 the buildings (Cattaneo 2019; Cattano et al. 2013). Barriers depend from the actors (owner, tenant, 50 utility, regulators, manufacturers, etc.), their role in energy efficiency project and the market, ACCEPTED VERSION SUBJECT TO FINAL EDITS Final Government Distribution Chapter 9 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 9-80 Total pages: 168 1 technology, financial economic, social, legal, institutional, regulatory and policy structures (Reddy 2 1991; Weber 1997; Sorrell et al. 2000; Reddy 2002; Sorrell et al. 2011: Cagno et al. 2012; Bardhan et 3 al., 2014; Bagaini et al. 2020; Vogel et al. 2015; Khosla et al. 2017; Gupta et al. 2017). Barriers 4 identified for the refurbishment of exiting building or construction of new efficient buildings includes: 5 lack of high-performance products, construction methods, monitoring capacity, investment risks, 6 policies intermittency, information gaps, principal agent problems (both tenant and landlord face 7 disincentives to invest in energy efficiency), skills of the installers, lack of a trained and ready 8 workforce, governance arrangements in collectively owned properties and behavioural anomalies. (Do 9 et al. 2020; Dutt 2020; Gillingham and Palmer 2014;Yang et al., 2019; Song et al. 2020; Buessler et al. | Heritage | 1581 - 1582 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 24 Progressive building energy codes include requirements on efficiency improvement but also on 25 sufficiency and share of renewables (Rosenberg at al., 2017; Clune at al. 2012) and on embodied 26 emissions (Schwarz et al. 2020), for example the 2022 ASHRAE Standard 90.1 includes prescriptive 27 on-site renewable energy requirements for non-residential building. Evans et al. (2017; 2018) calls for 28 strengthen the compliance checks with efficiency requirements or codes when buildings are in operation 29 and highlighted the need for enforcement of building energy codes to achieve the estimate energy and 30 carbon savings recommending actions to improve enforcements, including institutional capacity and 31 adequate resources. | Heritage | 1586 - 1586 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 25 The concept of carbon allowances or carbon budget can also be applied to buildings, by assigning a 26 yearly CO2 emissions budget to each building. This policy would be a less complex than personal 27 allowances as buildings have metered or billed energy sources (e.g., gas, electricity, delivered heat, 28 heating oil, etc.). The scheme stimulates investments in energy efficiency and on-site renewable 29 energies and energy savings resulting from behaviour by buildings occupant. For commercial buildings, 30 similar schemes were implemented in the UK CRC Energy Efficiency Scheme (closed in 2019) or the 31 Tokyo Metropolitan Carbon and Trade Scheme (Nishida and Hua 2011)(Bertoldi et al. 2013a). The 32 Republic of Korea implemented since 2015 an Emission Trading Scheme, covering buildings (Park and 33 Hong 2014; Narassimhan et al. 2018; Lee and Yu 2017). More recently under the New York Climate 34 Mobilization Act enacted in 2019 New York City Local Law 97 established "Carbon Allowances" for 35 large buildings (Spiegel-Feld, 2019; Lee, 2020). | Heritage | 1589 - 1589 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 40 9.9.5 Policies mechanisms for financing for on-site renewable energy generation 41 On-site renewable energy generation is a key component for the building sector decarbonisation, 42 complementing sufficiency and efficiency. Renewable energies (RES) technologies still face barriers 43 due to the upfront investment costs, despite the declining price of some technologies, long pay-back 44 period, unpredictable energy production, policy incertitude, architectural (in particular for built-in PV) 45 and landscape considerations, technical regulations for access to the grid, and future electricity costs 46 (Mah et al. 2018; Agathokleous and Kalogirou 2020). | Heritage | 1592 - 1592 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 16 A flat rate feed-in tariff (FiT) is a well-tested incentive adopted in many jurisdictions to encourage end- 17 users to generate electricity from RES using rooftop and on-site PV systems (Pacudan 2018). More 18 recently, there has been an increasing interest for dynamic FiTs taking into account electricity costs, 19 hosting capacity, ambient temperature, and time of day (Hayat et al. 2019). Since 2014, EU Member 20 States have been obligated to move from FiT to feed-in premium (FiTP) (Hortay and Rozner 2019); 21 where a FiTP consist in a premium of top of the electricity market price. Lecuyer and Quirion (2019) 22 argued that under uncertainty over electricity prices and renewable production costs a flat FiT results 23 in higher welfare than a FiTP. One of the main concerns with FiT systems is the increasing cost of 24 policies maintenance (Pereira da Silva et al. 2019; Roberts et al. 2019a; Zhang et al. 2018). In Germany, 25 the financial costs, passed on to consumers in the form a levy on the electricity price have increased 26 substantially in recent years (Winter and Schlesewsky 2019) resulting in opposition to the FiT in 27 particular by non-solar customers. A particular set up of the FiT encourage self-consumption through 28 net metering and net billing, which has a lower financial impact on electricity ratepayers compared with 29 traditional FiTs (Roberts et al. 2019b; Vence and Pereira 2019; Pacudan 2018). | Heritage | 1593 - 1593 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 11 Tenders are a fast spreading and effective instrument to attract and procure new generation capacity 12 from renewable energy sources (Bayer et al. 2018; Bento et al. 2020; Ghazali et al. 2020; Haelg 2020; 13 Batz T. and Musgens 2019). A support scheme based on tenders allows a more precise steering of 14 expansion and lower risk of excessive support (Gephart et al. 2017). Bento et al. (2020) indicated that 15 tendering is more effective in promoting additional renewable capacity comparing to other mechanisms 16 such as FiTs. It is also important to take into account the rebound effect in energy consumption by on- 17 site PV users, which might reduce up to one fifth of the carbon benefit of renewable energy (Deng and 18 Newton 2017). | Heritage | 1594 - 1594 |

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| Organisation | Document | Quotation Content | Codes | Page |
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| IPCC | IPCC_AR6_WGIII_Full_Report | 39 Building energy consumption is dependent on local climate and building construction traditions, 40 regional and local government share an important role in promoting energy efficiency in buildings and 41 on-site RES, through local building energy codes, constructions permits and urban planning. In South 42 Korea, there is a green building certification system operated by the government, based on this, Seoul 43 has enacted Seoul's building standard, which includes more stringent requirements. Where it is difficult 44 to retrofit existing buildings, e.g., historical buildings, cities may impose target at district level, where 45 RES could be shared among buildings with energy positive buildings compensating for energy 46 consuming buildings. Local climate and urban plans could also contribute to the integration of the 47 building sector with the local transport, water, and energy sectors, requiring, for example, new 48 constructions in areas served by public transport, close to offices or buildings to be ready for e-mobility. | Heritage | 1596 - 1596 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 25 There are three categories of GHG emissions from buildings: 26 i. direct emissions which are defined as all on-site fossil fuel or biomass-based combustion 27 activities (i.e., use of biomass for cooking, or gas for heating and hot water) and F-gas emissions 28 (i.e., use of heating and cooling systems, aerosols, fire extinguishers, soundproof) 29 ii. indirect emissions which occur off-site and are related to heat and electricity production 30 iii. embodied emissions which are related to extracting, producing, transforming, transporting, and 31 installing the construction material and goods used in buildings 32 In 2019, global GHG emissions from buildings were at 12 GtCO2-eq out of which 24% were direct 33 emissions, 57% were indirect emissions, and 18% were embodied emissions. More than 95% of 34 emissions from buildings were CO2 emissions, CH4 and N2O represented 0.08% each and emissions 35 from halocarbon contributed by 3% to global GHG emissions from buildings. | Heritage | 1599 - 1599 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 38 Mitigation actions in buildings generate multiple co-benefits (e.g., health benefits due to the improved 39 indoor and outdoor conditions, productivity gains in non-residential buildings, creation of new jobs 40 particularly at local level, improvements in social wellbeing etc.) beyond their direct impact on reducing 41 energy consumption and GHG emissions. Most studies agree that the value of these multiple benefits 42 is greater than the value of energy savings and their inclusion in economic evaluation of mitigation ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 9 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 9-98 Total pages: 168 1 actions may improve substantially their cost-effectiveness. It is also worth mentioning that in several 2 cases the buildings sector is characterized by strong rebound effects, which could be considered as a 3 co-benefit in cases where the mechanisms involved provide faster access to affordable energy but also 4 a trade-off in cases where the external costs of increased energy consumption exceed the welfare 5 benefits of the increased energy service consumption, thus lowering the economic performance of 6 mitigation actions. The magnitude of these co-benefits and trade-offs are characterized by several 7 uncertainties, which may be even higher in the future as mitigation actions will be implemented in a 8 changing climate, with changing building operation style and occupant behaviour. Mitigation measures 9 influence the degree of vulnerability of buildings to future climate change. For instance, temperature 10 rise can increase energy consumption, which may lead to higher GHG emissions. Also, sea level rise, 11 increased storms and rainfall under future climate may impact building structure, materials and 12 components, resulting in increased energy consumption and household expenditure from producing and 13 installing new components and making renovations. Well-planned energy efficiency, sufficiency and 14 on-site renewable energy production can help to increase building resilience to climate change impacts 15 and reduce adaptation needs. | Heritage | 1599 - 1600 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 18 Several barriers (information, financing, markets, behavioural, etc.) still prevents the decarbonisation 19 of buildings stock, despite the several co-benefits, including large energy savings. Solutions include 20 investments in technological solutions (e.g., insulation, efficient equipment, and low-carbon energies 21 and renewable energies) and lifestyle changes. In addition, the concept of sufficiency is suggested to be 22 promoted and implemented through policies and information, as technological solutions will be not 23 enough to decarbonise the building sector. Due to the different types of buildings, occupants, and 24 development stage there is not a single policy, which alone will reach the building decarbonisation 25 target. A range of policy instruments ranging from regulatory measures such as building energy code 26 for NZEBs and appliance standards, to market-based instruments (carbon tax, personal carbon 27 allowance, renewable portfolio standards, etc.), and information. Financing (grants, loans, performance 28 base incentives, pays as you save, etc.) is another key enabler for energy efficiency technologies and 29 on-site renewables. Finally, effective governance and strong institutional capacity are key to have an 30 effective and successful implementation of policies and financing. | Heritage | 1600 - 1600 |

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| Organisation | Document | Quotation Content | Codes | Page |
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| IPCC | IPCC_AR6_WGIII_Full_Report | 22 {10.3, 10.8} 23 Legislated climate strategies are emerging at all levels of government, and, together with pledges 24 for personal choices, could spur the deployment of demand and supply-side transport mitigation 25 strategies (medium confidence). At the local level, legislation can support local transport plans that 26 include commitments or pledges from local institutions to encourage behaviour change by adopting an 27 organisational culture that motivates sustainable behaviour with inputs from the creative arts. Such 28 institution-led mechanisms could include bike-to-work campaigns, free transport passes, parking 29 charges, or eliminating car benefits. Community-based solutions like solar sharing, community 30 charging, and mobility as a service can generate new opportunities to facilitate low-carbon transport 31 futures. At the regional and national levels, legislation can include vehicle and fuel efficiency standards, 32 R&D support, and large-scale investments in low-carbon transport infrastructure. {10.8, Chapter 15} 33 34 ACCEPTED VERSION SUBJECT TO FINAL EDITS Final Government Distribution Chapter 10 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 10-7 Total pages: 176 1 10.1 Introduction and overview 2 This chapter examines the transport sector's role in climate change mitigation. It appraises the transport 3 system's interactions beyond the technology of vehicles and fuels to include the full life cycle analysis 4 of mitigation options, a review of enabling conditions, and metrics that can facilitate advancing 5 transport decarbonisation goals. The chapter assesses developments in the systems of land-based 6 transport and introduces, as a new feature since AR5, two separate sections focusing on the trends and 7 challenges in aviation and shipping. The chapter assesses the future trajectories emerging from global, 8 energy, and national scenarios and concludes with a discussion on enabling conditions for 9 transformative change in the sector. | Heritage | 1676 - 1677 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 35 While much attention has been given to engine and fuel technologies to mitigate GHG emissions from 36 the transport sector, population dynamics, finance and economic systems, urban form, culture, and 37 policy also drive emissions from the sector. Thus, systemic change requires innovations in these 38 components. These systemic changes offer the opportunity to decouple transport emissions from 39 economic growth. In turn, such decoupling allows environmental improvements like reduced GHG 40 emissions without loss of economic activity (UNEP 2011, 2013; Newman et al. 2017; IPCC 2018). | Heritage | 1683 - 1683 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 19 Avoid - the effect of prices and income on demand: Research has shown that household income and 20 price have a strong influence on people's preferences for transport services (Bakhat et al. 2017; Palmer 21 et al. 2018). The relationship between income and demand is defined by the income elasticity of 22 demand. For example, research suggests that in China, older and wealthier populations continued to 23 show a preference for car travel (Yang et al. 2019) while younger and low-income travellers sought 24 variety in transport modes (Song et al. 2018). Similarly, (Bergantino et al. 2018b) evaluated the income 25 elasticity of transport by mode in the UK. They found that the income elasticity for private cars is 0.714, 26 while the income elasticities of rail and bus use are 3.253 (The greater elasticity the greater the demand 27 will grow or decline, depending on income). Research has also shown a positive relationship between 28 income and demand for air travel, with income elasticities of air travel demand being positive and as 29 large as 2 (Gallet and Doucouliagos 2014; Valdes 2015; Hakim and Merkert 2016, 2019; Hanson et al. | Heritage | 1686 - 1686 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 18 There is growing evidence that this more structured form of behavioural change through shared 19 economy practices, supported by a larger group than a single family, has a much greater potential to 20 save transport emissions, especially when complemented with decarbonised grid electricity (Greenblatt 21 and Shaheen 2015; Sharp 2018). Carpooling, for example, could result in an 11% reduction in vkm and 22 a 12% reduction in emissions, as carpooling requires less empty or non-productive passenger- 23 kilometres (pkm) (ITF 2020a,b). However, the use of local shared mobility systems such as on-demand 24 transport may create more transport emissions if there is an overall modal shift out of transit (ITF 2018a; 25 Schaller 2018). Similarly, some work suggests that commercial shared vehicle services such as Uber 26 and Lyft are leading to increased vehicle kms travelled (and associated GHG emissions) in part due to 27 deadheading (Schaller 2018; Tirachini and Gomez-Lobo 2020; Ward et al. 2021). Successful providers 28 compete by optimising personal comfort and convenience rather than enabling a sharing culture 29 (Eckhardt and Bardhi 2015), and concerns have been raised regarding the wider societal impacts of 30 these systems and for specific user groups such as older people (Fitt 2018; Marsden 2018). Concerns 31 have also been expressed over the financial viability of demand-responsive transport systems (Ryley et 32 al. 2014; Marsden 2018), how the mainstreaming of shared mobility systems can be institutionalised 33 equitably, and the operation and governance of existing systems that are only mode and operator- 34 focused (Akyelken et al. 2018; Jittrapirom et al. 2018; Pangbourne et al. 2020; Marsden 2018). | Heritage | 1689 - 1689 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 16 2018). All three of these technologies rely on making use of relatively inexpensive elements, which can 17 help bring down battery costs (Cano et al. 2018). The main challenge these technologies face is in terms 18 of the cycle life. Out of the three, Li-S has already been used for applications in unmanned aerial 19 vehicles (Fotouhi et al., 2017) due to relatively high specific energy (almost double the state of art 20 LIBs). However, even with low cycle life, Li-air and Zn-air hold good prospects for commercialisation 21 as range extender batteries for long-range road transport and with vehicles that are typically used for 22 city driving (Cano et al. 2018). | Heritage | 1702 - 1702 |

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| IPCC | IPCC_AR6_WGIII_Full_ Report | 22 Ammonia, synthetic fuels, and biofuels have emerged as alternative fuels for powering combustion 23 engines and turbines used in land, shipping, and aviation (Figure 10.2). Synthetic fuels such as e- 24 Methanol and Fischer-Tropsch liquids have similar physical properties and could be used with existing 25 fossil fuel infrastructure (Soler, 2019). Similarly, biofuels have been used in several countries together 26 with fossil fuels (Panoutsou et al. 2021). Ammonia is a liquid, but only under pressure, and therefore 27 will not be compatible with liquid fossil fuel refuelling infrastructure. Ammonia is, however, widely 28 used as a fertiliser and chemical raw material and 10% of annual Ammonia production is transported 29 via sea (Gallucci 2021). As such, a number of port facilities include Ammonia storage and transport 30 infrastructure and the shipping industry has experience in handling Ammonia (Gallucci 2021). This 31 infrastructure would likely need to be extended in order to support the use of Ammonia as a fuel for 32 shipping and therefore ports are likely to be the primary sites for these new refuelling facilities. | Heritage | 1704 - 1704 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | 15 While charging infrastructure is of high importance for the electrification of light-duty vehicles, 16 arguably, it is even more important for heavy-duty vehicles given the costs of high-power charging 17 infrastructure. It is estimated that the installed cost of fast-charging hardware can vary between 18 approximately USD 45,000 to 200,000 per charger, depending on the charging rate, the number of 19 chargers per site, and other site conditions (Nicholas 2019; Hall and Lutsey 2019; Nelder and Rogers 20 2019). Deployment of shared charging infrastructure at key transport hubs, such as bus and truck depots, 21 freight distribution centres, marine shipping ports and airports, can encourage a transition to electric 22 vehicles across the heavy transport segments. Furthermore, if charging infrastructure sites are designed 23 to cater for both light and heavy-duty vehicles, infrastructure costs could decrease by increasing 24 utilisation across multiple applications and/or fleets (Nelder and Rogers 2019). | Heritage | 1705 - 1705 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | 3 The design of Hydrogen refuelling stations depends on the choice of methods for Hydrogen supply and 4 delivery, compression and storage, and the dispensing strategy. Hydrogen supply could happen via on- 5 site production or via transport and delivery of Hydrogen produced off-site. At the compression stage, 6 Hydrogen is compressed to achieve the pressure needed for economic stationery and vehicle storage. | Heritage | 1707 - 1707 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | 11 If Hydrogen is produced off site in a large centralised plant, it must be stored and delivered to refuelling 12 stations. The cost of Hydrogen delivery depends on the amount of Hydrogen delivered, the delivery 13 distance, the storage method (compressed gas or cryogenic liquid), and the delivery mode (truck vs. | Heritage | 1707 - 1707 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | 14 pipeline). Table 10.6 describes the three primary options for Hydrogen delivery. Most Hydrogen 15 refuelling stations today are supplied by trucks and, very occasionally, Hydrogen pipelines. Gaseous 16 tube trailers could also be used to deliver Hydrogen in the near term, or over shorter distances, due to 17 the low fixed cost (although the variable cost is high). Both liquefied truck trailers and pipelines are 18 recognised as options in the medium to long-term as they have higher capacities and lower costs over 19 longer distances (FCHJU 2019; Li et al. 2020; EU 2021).Alternatively, Hydrogen can be produced on 20 site using a small-scale onsite electrolyser or steam methane reforming unit combined with CCS. | Heritage | 1707 - 1707 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | 9 FCVs represent the most expensive solution for LDV, mainly due to the currently higher purchase price 10 of the vehicle itself. However, given the lower technology readiness level of FCVs and the current 11 efforts in the research and development of this technology, FCVs could become a viable technology for 12 LDVs in the coming years. The issues regarding the extra energy involved in creating the Hydrogen 13 and its delivery to refuelling sites remain, however. The levelized cost of Hydrogen on a per GJ basis 14 is lower than conventional fossil fuels but higher than electricity. In addition, within the levelized cost 15 of Hydrogen, there are significant cost differences between the Hydrogen producing technologies. | Heritage | 1716 - 1716 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | 13 14 Figure 10.8 presents a review of life cycle GHG emissions from land-based freight technologies (heavy 15 and medium-duty trucks, and rail). Each panel within the figure represents data in GHG emissions per 16 tkm of freight transported by different technology and/or fuel types, as indicated by the labels to the 17 left. The data in each panel came from a number of relevant scientific studies (Merchan et al. 2020; 18 Frattini et al. 2016; Zhao et al. 2016; CE Delft 2017; Isaac and Fulton 2017; Song et al. 2017; Cooper 19 and Balcombe 2019; S. Mojtaba et al. 2019; Nahlik et al. 2016; Prussi et al. 2020; Hill et al. 2020; Liu 20 et al. 2020a; Valente et al. 2021; Gray et al. 2021; Valente et al. 2017; Tong et al. 2015a). Similar to 21 the results for buses, technologies that offer substantial emission reductions for freight include: ICEV 22 trucks powered with the low carbon variants for biofuels, Ammonia or synthetic diesel; BEVs charged 23 with low carbon electricity; and FCVs powered with renewable-based electrolytic Hydrogen, or 24 Ammonia. Since Ammonia and Fischer-Tropsch diesel are produced from Hydrogen, their emissions 25 are higher than the source Hydrogen, but their logistical advantages over Hydrogen are also a 26 consideration (as discussed in Section 10.3). | Heritage | 1724 - 1724 |

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| IPCC | IPCC_AR6_WGIII_Full_Report | 25 Increased Arctic shipping activity may also impose increased risks to local marine ecosystems and 26 coastal communities from invasive species, underwater noise, and pollution (Halliday et al. 2017; IPCC 27 2019). Greater levels of Arctic maritime transport and tourism have political, as well as socio-economic 28 implications for trade, and nations and economies reliant on the traditional shipping corridors. There 29 has been an increase in activity from cargo, tankers, supply, and fishing vessels in particular (Zhao et 30 al. 2015; Winther et al. 2014). Projections indicate more navigable Arctic waters in the coming decades 31 (Smith and Stephenson 2013; Melia et al. 2016) and continued increases in transport volumes through 32 the northern sea routes (Winther et al. 2014; Corbett et al. 2010; Lasserre and Pelletier 2011). Emission 33 patterns and quantities, however, are also likely to change with future regulations from IMO, and 34 depend on technology developments, and activity levels which may depend upon geopolitics, 35 commodity pricing, trade, natural resource extractions, insurance costs, taxes, and tourism demand 36 (Johnston et al. 2017). The need to include indigenous peoples' voices when shaping policies and 37 governance of shipping activities in the high north is increasing (Dawson et al. 2020). | Heritage | 1739 - 1739 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 28 Traditionally there is a disconnection between IAM models and bottom-up sectoral or city-based 29 models due to the different scale (both spatial and temporal) and focus (climate mitigation vs. urban 30 pollutions, safety (Creutzig 2016)). The proliferation of shared and on-demand mobility solutions are 31 leading to rebound effects for travel demand (Chen and Kockelman 2016; Coulombel et al. 2019) and 32 this is a new challenge for modelling. Some IAM studies have recently begun to explore demand-side 33 solutions for reducing transport demand to achieve very low-carbon scenarios through a combination 34 of culture and low-carbon lifestyle (Creutzig et al. 2018; van Vuuren et al. 2018); urban development 35 (Creutzig et al. 2015a); increased vehicle occupancy (Grubler et al. 2018); improved logistics and 36 streamline supply chains for the freight sector (Mulholland et al. 2018); and disruptive low-carbon 37 innovation, described as technological and business model innovations offering "novel value 38 propositions to consumers and which can reduce GHG emissions if adopted at scale" (Wilson et al. | Heritage | 1752 - 1752 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 43 END BOX HERE 44 45 Enabling creative foresight: Human culture has always had a creative instinct that enables the future to 46 be better dealt with through imagination (Montgomery 2017). Science and engineering have often been ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 10 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 10-99 Total pages: 176 1 preceded by artistic expressions such as Jules Verne, who first dreamed of the Hydrogen future in 1874 2 in his novel The Mysterious Island. Autonomous vehicles have regularly occupied the minds of science 3 fiction authors and filmmakers (Braun 2019). Such narratives, scenario building, and foresighting are 4 increasingly seen as a part of the climate change mitigation process (Lennon et al. 2015; Muiderman et 5 al. 2020) and can 'liberate oppressed imaginaries' (Luque-Ayala 2018). (Barber 2021) have emphasised 6 the important role of positive images about the future instead of dystopian visions and the impossibility 7 of business-as-usual futures. | Heritage | 1768 - 1769 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 13 The state-of-the-art Lithium-Ion Batteries (LIBs) available in 2020 are superior to alternative cell 14 technologies in terms of battery life, energy density, specific energy, and cost. The expected further 15 improvements in LIBs suggest these chemistries will remain superior to alternative battery technologies 16 in the medium-term, and therefore LIBs will continue to dominate the electric vehicle market. | Heritage | 1773 - 1773 |
| IPCC | IPCC_AR6_WGIII_Full_Report | However, blue hydrogen production pathways may generate air pollutants nearby the production sites. | Heritage | 1837 - 1837 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 2 A common platform for sharing information and enhancing communication among industrial 3 stakeholders through the application of information and telecommunication technologies is helpful for 4 facilitating the creation of industrial symbiosis. The main benefit of industrial symbiosis is the overall 5 reduction of both virgin materials and final wastes, as well as reduced/avoided transportation costs from 6 byproduct exchanges among tenant companies, which can specifically help small and medium sized 7 enterprises to improve their growth and competitiveness. From climate perspective, this indicates 8 significant industrial emission mitigation since the extraction, processing of virgin materials and the 9 final disposal of industrial wastes are more energy-intensive. Also, careful site selection of such parks 10 can facilitate the use of renewable energy. Due to these advantages, eco-industrial parks have been 11 actively promoted, especially in East Asian countries, such as China, Japan and South Korea, where 12 national indicators and governance exist (Geng et al. 2019). For instance, the successful implementation 13 of industrial symbiosis at Dalian Economic and Technological Development Zone has achieved 14 significant co-benefits, including GHG emission reduction, economic and social benefits and improved 15 ecosystem functions (Liu et al. 2018). Another case at Ulsan industrial park, South Korea, estimated 16 that 60,522 tonnes CO2 were avoided annually through industrial symbiosis between two companies 17 (Kim et al. 2018b). The case of China shows a great potential of implementing these measures, 18 estimating 111 million tonne CO2 equivalent will be reduced in 213 national-level industrial parks in 19 2030 compared with 2015 (Guo et al. 2018). As such, South Korea's national eco-industrial park project 20 has reduced over 4.7 million tonne CO2 equivalent through their industrial symbiosis efforts (Park et al. | Heritage | 1874 - 1874 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 17 There is a large identified potential for direct solar heating in industry, especially in regions with strong 18 solar insolation and sectors with lower heat needs (<180C), for example, food and beverage processing, 19 textiles, and pulp and paper (Schoeneberger et al. 2020). The key challenges to adoption are site and 20 use specificity, capital intensity, and a lack of standardized, mass manufacturing for equipment and 21 supply chain to provide them. | Heritage | 1878 - 1878 |

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| IPCC | IPCC_AR6_WGIII_Full_ Report | 23 There are several post-combustion CCS projects underway globally (IEA 2019g), generally focussed 24 on energy production and processing rather than industry. Their costs are higher but evolving downward – (Giannaris et al. 2020) suggest 47 USD·tCO2 -1 25 for a follow up 90% capture power generation plant 26 based on learnings from the Saskpower Boundary Dam pilot – but crucially these costs are higher than 27 implicit and explicit carbon prices almost everywhere, resulting in limited investment and learning in 28 these technologies. A key challenge with all CCS strategies, however, is building a gathering and 29 transport network for CO2, especially from dispersed existing sites; hence most pilot are built near 30 EOR/geological storage sites, and the movement towards industrial clustering in the EU and UK 31 (UKCCC 2019b), and as suggested in (IEA 2019f). | Heritage | 1882 - 1882 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | 8 Circular economy introduces itself throughout, but mainly at the front end when designing materials 9 and processes to be more materially efficient, efficient in use, and easy to recycle, and at the back end, 10 when a material or product's services life has come to end, and it is time for recycling or sustainable 11 disposal (Korhonen et al. 2018; Murray et al. 2017). The entire chain's potential will be maximized 12 when these strategies are designed in ahead of time instead of considered on assembly, or as a retrofit 13 (Material Economics 2019; Allwood et al. 2012; Gonzalez Hernandez et al. 2018a; IEA 2019b; Bataille 14 2020a). For example, when designing a building: 1) Is the building shell, interior mass and ducting 15 orientated for passive heating and cooling, and can the shell and roof have building integrated solar PV 16 or added easily, with hard-to-retrofit wiring already incorporated? 2) Are steel and high quality concrete 17 only used where really needed (i.e. for shear, tension and compression strength), can sections be 18 prefabricated off-site, can other materials be substituted, such as wood? 3) Can the interior fittings be 19 built with easy to recycle plastics or other sustainably disposable materials (e.g. wood)? 4) Can this 20 building potentially serve multiple purposes through its anticipated lifetime, are service conduits 21 oversized and easy to access for retrofitting? 5) When it is time to be taken apart, can pieces be reused, 22 and all componnents recycled at high purity levels, for example, can all the copper wiring be easily be 23 found and removed, are the steel beams clearly tagged with their content? The answers to these 24 questions will be very regionally and site specific, and require revision of educational curricula for the 25 entire supply chain, as well as revision of building codes. | Heritage | 1885 - 1885 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | 23 Reflecting the different conditions at existing and potential future plant sites, when choosing one of the 24 above options a combination of different measures and structural changes (including electricity, 25 hydrogen and CCU or CCS infrastructure needs) will likely be necessary in the future to achieve deep 26 reductions in CO2 emissions of steel production. | Heritage | 1891 - 1891 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | Hydrogen as CH4 replacement <=10% 9 See above Today Biogas or liquid replacement hydrocarbons 60–90% 9 Biomass USD/GJ; >=50 USD/t, uncertain Today Anaerobic digestion/fermentation: CH4, CH3OH, C2H5OHxii Up to -99% 9 Biomass cost Today Methane or methanol from H2 & COx (CCUS for excess). Maximum -50% reduction if C source is FF 50–99% 6–9 Cost: H2 & COx Today 850°C woody biomass gasification w/ CCS for excess carbon: CO, CO2, H2, H2O, CH4, C2H4 & C6H6 xiii Could be negative 7–8 about 50–75 USD/t, uncertain Today Direct air capture for short and long chain CoOxHy xiv Up to 99% 3 Cost: E, H2, COx about 94–232 USD/t <=2030 1 i Data for CCS costs for steel making: Birat (2012); Axelson et al. (2018) and Leeson et al. (2017); ii Data for Hisarna: Axelson et al. (2018); iii Data for hydrogen DRI electric arc furnaces: Fischedick et al. (2014b) and Vogl et al. (2018); iv Data for molten oxide electrolysis (also known as SIDERWIN): (Axelson et al. 2018; Fischedick et al. 2014b). The TRLs differ by source, the value provided is from Axelson et al. (2018) based on UCLOS SIDERWIN; v Data for making hydrogen from SMR and ATR with CCUS: Moore (2017), Leeson et al. (2017) and IEA (2019f). The cost of CCS disposal of concentrated sources of CO2 at 15–40 USD·tCO2-eq-1 is well established as commercial for direct or EOR purposes and is based on the long standing practise of disposing of hydrogen sulfide and oil brines underground: Wilson et al. (2003) and Leeson et al. (2017). There is a wide variance, however, in estimated tCO2-eq-1 breakeven prices for industrial post-combustion capture of CO2 from sources highly diluted in nitrogen (e.g. Leeson et al. (2017) at 60–170 USD·tCO2-eq-1 ), but most fall under 120 USD·tCO2-eq-1 ; vi Data for clinker substitution and use of well mixed and multi sized aggregates: (Fechner and Kray 2012; Lehne and Preston 2018; Habert et al. 2020); vii Rio Tinto, Alcoa and Apple have partnered with the governments of Québec and Canada to formed a coalition to commercialize inert as opposed to sacrificial graphite electrodes by 2024, thereby making the standard Hall Heroult process very low emissions if low carbon electricity is used; viii Data and other information: Bazzanella and Ausfelder (2017); Axelson et al. (2018); IEA (2018a); De Luna et al. (2019) and Philibert (2017b,a); ix See De Luna et al. (2019) for a state of the art review of electrocatalysis, or direct recombination of organic molecules using electricity and catalysts; x Data for hydrogen production from electrolysis: Bazzanella and Ausfelder (2017); Philibert (2017a); Armijo and Philibert (2020); IEA (2019f); Philibert (2017b); xi Data for methane pyrolysis to make hydrogen: Abbas and Wan Daud (2010). Data for hydrogen production from methane catalytic cracking: Amin et al. (2011) and Ashik et al. (2015); xii Data for anaerobic digestion or fermentation for the production of methane, methanol and ethanol: De Luna et al. (2019); xiii Data for woody biomass gasification: Li et al. (2019) and van der Meijden et al. (2011); xiv Data on direct air capture of CO2: Keith et al. (2018) and Fasihi et al. (2019). | Heritage | 1903 - 1903 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | 35 Using industrial waste heat for space heating, via district heating, is an established practice that still has 36 a large potential with large quantities of low-grade heat being wasted (Fang et al. 2015). For Denmark 37 it is estimated that 5.1% of district heating demand could be met with waste heat (Bühler et al. 2017) 38 and for four towns studied in Austria 3-35% of total heat demand could be met (Karner et al. 2016). A 39 European study shows that temporal heat demand flexibility could allow for up to 100% utilization of 40 excess heat from industry (Karner et al. 2018). A study of a Swedish chemicals complex estimated that 41 30-50% of excess heat generated on-site could be recovered with payback periods below 3 years 42 (Eriksson et al. 2018). | Heritage | 1921 - 1921 |

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| IPCC | IPCC_AR6_WGIII_Full_ Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS Final Government Distribution Chapter 11 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 11-76 Total pages: 135 1 With increasing shares of renewable electricity production there is a growing interest in industrial 2 demand response, storage and hybrid solutions with on-site PV and CHP (Schriever and Halstrup 2018; 3 Scheubel et al. 2017; Shoreh et al. 2016). With future industrial electrification, and in particular with 4 hydrogen used as reduction agent in ironmaking or as feedstock in the chemicals industry, the level of 5 interaction between industry and power systems becomes very high. Large amounts of coking coal, or 6 oil and gas as petrochemical energy and feedstock, are then replaced by electricity. For example, Meys 7 et al. (2021) estimates a staggering future electricity demand of 10,000 TWh in a scenario for a net zero 8 emissions plastics production of 1100 Mt in 2050 (see 11.3.5 for other estimates of electricity demand). | Heritage | 1921 - 1922 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | 18 Many studies report that energy efficiency improvements are essential for supporting overall economic 19 growth, contributing to positive changes in multi-factor productivity (SDG 8 - Decent Work and 20 Economic Growth & Industry, Innovation, and Infrastructure) (Bashmakov 2019; Bataille and Melton 21 2017; Stern 2019; Lambert et al. 2014; Rajbhandari and Zhang 2018) through industrial innovation 22 (SDG 9) (Kang and Lee 2016), with some dissent e.g., (Mahmood and Ahmad 2018). Improved energy 23 efficiency against a background of growing energy prices helps industrial plants stay competitive 24 (Bashmakov and Myshak 2018). Energy efficiency allows continued economic growth under strong 25 environmental regulation. Given that energy efficiency measures reduce the combustion of fossil fuels 26 it leads to reduced air pollution at industrial sites (Williams et al. 2012) and better indoor comfort at 27 working places. | Heritage | 1928 - 1928 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | 14 Assessments of pricing mechanisms show generally that they lead to reduced emissions, even in sectors 15 that receive free allocation such as industry (Bayer and Aklin 2020; Narassimhan et al. 2018; Martin et 16 al. 2016; Haites et al. 2018; Metcalf 2019). However, questions remain as to whether these schemes 17 can bring emissions down fast enough to reach the Paris Agreement goals (World Bank Group 2019; 18 Tvinnereim and Mehling 2018; Boyce 2018b). Most carbon prices are well below the levels needed to 19 motivate investments in high-cost options that are needed to reach net zero emissions (see Section 20 11.4.1.5). Among the 64 carbon price schemes implemented worldwide today, only nine have carbon 21 prices above 40 USD (World Bank 2020). These are all based in Europe and include EU Emissions 22 Trading System (ETS) (above 40 USD since March 2021), Switzerland ETS, and seven countries with 23 carbon taxes. Furthermore, emissions-intensive and trade-exposed (EITE) industries are typically 24 allowed exemptions and receive provisions that shelter them from any significant cost increase in ACCEPTED VERSION SUBJECT TO FINAL EDITS Final Government Distribution Chapter 11 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 11-86 Total pages: 135 1 virtually all pricing schemes (Haites 2018). These provisions have been allocated due to concerns about 2 loss of competitiveness and carbon leakage which result from relocation and increased imports from 3 jurisdictions with no, or weak, GHG emission regulations (Branger and Quirion 2014a; Jakob 2021a; 4 Branger and Quirion 2014b). Embodied emissions in international trade accounts for one quarter of 5 global $CO_2$ emissions in 2015 (Moran et al. 2018) and has increased significantly over the past few 6 decades, representing a significant challenge to competitiveness related to climate policy. CBAM, or 7 CBA) are trade-based mechanisms designed to ‘equalise’ the carbon costs for domestic and foreign 8 producers. They are increasingly being considered by policy makers to address carbon leakage and 9 create a level playing field for products produced in jurisdiction with no, or lower, carbon price 10 (Mehling et al. 2019; Markkanen et al. 2021). On 14 July 2021, the European Commission adopted a 11 proposal for a CBAM that requires importers of aluminium, cement, iron and steel, electricity and 12 fertiliser to buy certificates at the ETS price for the emissions embedded in the imported products 13 (European Commission 2021; Mörsdorf 2021). CBAMs should be crafted very carefully, to meet 14 technical and legal challenges (Rocchi et al. 2018; Sakai and Barrett 2016; Jakob et al. 2014; Cosbey et 15 al. 2019; Pyrka et al. 2020; Joltreau and Sommerfeld 2019). Technical challenges arise because 16 estimating the price adjustment requires reliable data on the GHG content of products imported as well 17 as a clear understanding of the climate policies implications from the countries of imports. Application 18 of pricing tools in industry requires standardization (benchmarking) of carbon intensity assessments at 19 products, installations, enterprises, countries, regions, and the global level. The limited number of 20 existing benchmarking systems are not yet harmonizeded and thus not able fulfill this function 21 effectively. This limits the scope of products that can potentially be covered by CBAM type policies 22 (Bashmakov et al. 2021a). | Heritage | 1931 - 1932 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | 15 2016). As a result, jurisdictions are increasingly considering new requirements in building codes to 16 reduce embodied emissions. This is the case of France’s new building code which is shifting from a 17 thermal regulation (RT 2012) to an environmental regulation (RE 2020) to include embodied GHG 18 LCA metrics for encouraging use of low-GHG building materials (Schwarz et al. 2020; Ministère de la 19 Transition écologique et solidaire 2018). The 2018 International Green Construction Code (IGCC) 20 provides technical requirements that can be adopted by jurisdictions for encouraging low GHG building 21 construction, which also covers minimum longevity and durability of structural, building envelope, and 22 hardscape materials (Art. 1001.3.2.3) (Celadyn 2014). Low GHG Building Rating Systems, such as 23 LEEDs, are voluntary standards which include specific requirements on material resources in their 24 rating scale. Trade-offs between energy performance achievement and material used in building 25 construction needs to be further assessed and considered as low GHG building code requirements 26 develop. Local governments can also lead the way by adopting standards for construction. This is the case of the county of Marin in California which specifies maximum embodied carbon in kgCO2-eq m-3 27 and maximum ordinary Portland cement content in lbs/yd3 28 for different levels of concrete compressive 29 strength (Marin County 2021). | Heritage | 1940 - 1940 |

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| Organisation | Document | Quotation Content | Codes | Page |
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| IPCC | IPCC_AR6_WGIII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS Final Government Distribution Chapter 11 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 11-98 Total pages: 135 1 Energy intensive production steps may move where clean resources are most abundant and relatively 2 inexpensive (Bataille et al. 2021a; Gielen et al. 2020). For example, steel making has historically located 3 itself near iron ore and coal resources whereas in the future it may be located near iron ore and zero 4 GHG electricity or close to carbon storage sites (Fischedick et al. 2014b; Vogl et al. 2018; Bataille 5 2020a). This indicates large changes in industrial and supply chain structure, with directly associated 6 needs for employment and skills. Some sectors will grow, and some will shrink, with differing skill 7 needs. Each new workforce cohort needs the general specific skill to provide the employment that is 8 needed at each stage in the transition, implicating a need for co-ordination with policies for education 9 and retraining. | Heritage | 1943 - 1944 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 25 12.3.1.1 Direct Air Carbon Capture and Storage (DACCS) 26 Direct air capture (DAC) is a chemical process to capture ambient CO2 from the atmosphere. Captured 27 CO2 can be stored underground (direct air capture carbon and storage, DACCS) or utilised in products 28 (direct air capture carbon and utilisation, DACCU). DACCS shares with conventional CCS the transport 29 and storage components but is distinct in its capture part. Because CO2 is a well-mixed GHG, DACCS 30 can be sited relatively flexibly, though its locational flexibility is constrained by the availability of low- 31 carbon energy and storage sites. Capturing the CO2 involves three basic steps: a) contacting the air, b) 32 capturing on a liquid or solid sorbent or a liquid solvent, c) regeneration of the solvent or the sorbent 33 (with heat, moisture and/or pressure). After capture, the CO2 stream can be stored underground or 34 utilised. The duration of storage is an important consideration; geological reservoirs or mineralisation 35 result in removal for > 1000 years. The duration of the removal through DACCU (Breyer et al. 2019) 36 varies with the lifetime of respective products (Wilcox et al. 2017; Gunnarsson et al. 2018; Bui et al. | Heritage | 2023 - 2023 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 3 Status: Enhanced weathering has been demonstrated in the laboratory and in small scale field trials 4 (TRL 3–4) but has yet to be demonstrated at scale (Beerling et al. 2018; Amann et al. 2020). The 5 chemical reactions are well understood (Gillman 1980; Gillman et al. 2001; Manning 2008), but the 6 behaviour of the crushed rocks in the field and potential co-benefits and adverse-side effects of 7 enhanced weathering require further research (Beerling et al. 2018). Small scale laboratory experiments 8 have calculated weathering rates that are orders of magnitude slower than the theoretical limit for mass 9 transfer-controlled forsterite (Renforth et al. 2015; Amann et al. 2020) and basalt dissolution (Kelland 10 et al. 2020). Uncertainty surrounding silicate mineral dissolution rates in soils, the fate of the released 11 products, the extent of legacy reserves of mining by-products that might be exploited, location and 12 availability of rock extraction sites, and the impact on ecosystems remain poorly quantified and require 13 further research to better understand feasibility (Renforth 2012; Moosdorf et al. 2014; Beerling et al. | Heritage | 2027 - 2027 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 41 Risks and impacts: Mining of rocks for enhanced weathering will have local impacts and carries risks 42 similar to that associated with the mining of mineral construction aggregates, with the possible 43 additional risk of greater dust generation from fine comminution and land application. In addition to 44 direct habitat destruction and increased traffic to access mining sites, there could be adverse impacts on 45 local water quality (Younger and Wolkersdorfer 2004). | Heritage | 2027 - 2027 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 16 Food regulations: Novel foods based on insects, microbial proteins or cellular agriculture must go 17 through authorisation processes to ensure compliance with food safety standards before they can be 18 sold to consumers. Several countries have ‘novel food’ regulations governing the approval of foods for 19 human consumption. For example, the European Commission, in its update of the Novel Food 20 Regulation in 2015, expanded its definition of novel food to include food from cell cultures, or that 21 produced from animals by non-traditional breeding techniques (EU 2015). | Heritage | 2072 - 2072 |

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| IPCC | IPCC_AR6_WGIII_Full_Report | 36 (2021) quantified a land footprint by the infrastructure of a pilot solar plant being three times the onsite 37 land area. Sonter et al. (2020b) found significant overlap of mining areas (82% targeting materials 38 needed for renewable energy production) and biodiversity conservation sites and priorities, suggesting 39 that strategic planning is critical to address mining threats to biodiversity (See section 12.5.4) along 40 with recycling and exploration of alternative technologies that use that use abundant minerals (See 41 Chapter 11, Box Critical Minerals and The Future of Electro-Mobility and Renewables) 42 There are also situations where expanding mitigation is more or less decoupled from additional land 43 use. The use of organic consumer waste, harvest residues and processing side-streams in the agriculture 44 and forestry sectors can support significant volumes of bio-based products with relatively lower land- 45 use change risks than dedicated biomass production systems (Hanssen et al. 2019; Spinelli et al. 2019; 46 Mouratiadou et al. 2020). Such uses can provide waste management solutions while increasing the 47 mitigation achieved from the land that is already used for agricultural and forest production. Bioenergy ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Draft Chapter 12 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 12-99 Total pages: 220 1 accounts for about 90% of renewable heat used in industrial applications, mainly in industries that can 2 use their own biomass waste and residues, such as the pulp and paper industry, food industry, and 3 ethanol production plants (see Chapters 6 and 11) (IEA 2020c). Heat and electricity produced on-site 4 from side-streams but not needed for the industrial processes can be sold to other users, e.g., district 5 heating systems. Surplus waste and residues can also be used to produce solid and liquid biofuels, or be 6 used as feedstock in other industries such as the petrochemical industry (IRENA 2018; Lock and Whittle 7 2018; Thunman et al. 2018; IRENA 2019; Haus et al. 2020; Chapters 6 and 11). Electrification and 8 improved process efficiencies can reduce GHG emissions and increase the share of harvested biomass 9 that is used for production of bio-based products (Johnsson et al. 2019; Madeddu et al. 2020; Lipiäinen 10 and Vakkilainen 2021; Rahnama Mobarakeh et al. 2021; Silva et al. 2021; Chapter 11). Besides 11 integrating solar thermal panels and solar PV into buildings and other infrastructure, floating solar PV 12 panels in, e.g., hydropower dams (Ranjbaran et al. 2019; Cagle et al. 2020; Haas et al. 2020; Lee et al. | Heritage | 2079 - 2080 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 7 Trade-offs between different ecosystem services, and between societal objectives including climate 8 change mitigation and adaptation, can be managed through integrated landscape approaches that aim to 9 create a mosaic of land uses, including conservation, agriculture, forestry and settlements (Freeman et 10 al. 2015; Nielsen 2016; Reed et al. 2016; Sayer et al. 2017) where each is sited with consideration of 11 land potential and socioeconomic objectives and context (Cowie et al. 2018) (limited evidence, high 12 agreement). | Heritage | 2083 - 2083 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 27 Another example of beneficial effects includes perennial grasses and woody crops planted to intercept 28 runoff and subsurface lateral flow, reducing nitrate entering groundwater and surface waterbodies (e.g 29 Woodbury et al. 2018; Femeena et al. 2018; Griffiths et al. 2019). In India, (Garg et al. 2011) found 30 desirable effects as a result of planting Jatropha on wastelands previously used for grazing (which could 31 continue in the Jatropha plantations): soil evaporation was reduced, as a larger share of the rainfall was 32 channelled to plant transpiration and groundwater recharge, and less runoff resulted in reduced soil 33 erosion and improved downstream water conditions. Thus, adverse effects can be reduced and synergies 34 achieved when plantings are sited carefully, with consideration of potential hydrological impacts (Davis 35 et al. 2013). | Heritage | 2083 - 2083 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 40 2021), while painting blades to increase the visibility can also reduce mortality due to collision (May et 41 al. 2020). Theoretical studies have suggested that wind turbines could lead to warmer night temperatures 42 due to atmospheric mixing (Keith et al. 2004), later confirmed through observation (Zhou et al. 2013), 43 although Vautard et al. (2014) found limited impact at scales consistent with climate policies. More 44 recent studies report mixed results; indications that the warming effect could be substantial with 45 widespread deployment Miller and Keith 2018b and conversely limited impacts on regional climate at 46 20% of US electricity from wind. (Pryor et al. 2020). | Heritage | 2085 - 2085 |
| IPCC | IPCC_AR6_WGIII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Draft Chapter 12 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 12-105 Total pages: 220 1 Solar power 2 As for wind power, land impacts of solar power depend on the location, size and type of installation 3 (Ioannidis and Koutsoyiannis 2020). Establishment of large-scale solar farms could have positive or 4 negative environmental effects at the site of deployment, depending on the location. Solar PV and CSP 5 power installations can lock away land areas, displacing other uses (Mohan 2017). Solar PV can be 6 deployed in ways that enhance agriculture: for example, Hassanpour Adeh et al. (2018) found that 7 biomass production and water use efficiency of pasture increased under elevated solar panels. PV 8 systems under development may achieve significant power generation without diminishing agricultural 9 output (Miskin et al. 2019). Global mapping of solar panel efficiency showed that croplands, grasslands 10 and wetlands are located in regions with the greatest solar PV potential (Adeh et al. 2019). Dual-use 11 agrivoltaic systems are being developed that overcome previously recognised negative impact on crop 12 growth, mainly due to shadows (Armstrong et al. 2016; Marrou et al. 2013b,a), thus facilitating 13 synergistic co-location of solar photovoltaic power and cropping (Miskin et al. 2019; Adeh et al. 2019). | Heritage | 2085 - 2086 |

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| IPCC | IPCC_AR6_WGIII_Full_Report | 17 Deserts can be well-suited for solar PV and CSP farms, especially at low latitudes where global 18 horizontal irradiance is high, as there is lower competition for land and land carbon loss is minimal, 19 although remote locations may pose challenges for power distribution (Xu et al. 2016). Solar arrays can 20 reduce the albedo, particularly in desert landscapes, which can lead to local temperature increases and 21 regional impacts on wind patterns (Millstein and Menon 2011). Modelling studies suggest that large- 22 scale wind and solar farms, for example in the Sahara (Li et al. 2018), could increase rainfall through 23 reduced albedo and increased surface roughness, stimulating vegetation growth and further increasing 24 regional rainfall (Li et al. 2018) (limited evidence). Besides impacts at the site of deployment, wind 25 and solar power affect land through mining of critical minerals required by these technologies (Viebahn 26 et al. 2015; McLellan et al. 2016; Carrara et al. 2020). | Heritage | 2086 - 2086 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 14 Hydropower projects may impact aquatic ecology and biodiversity, necessitate the relocation of local 15 communities living within or near the reservoir or construction sites and affect downstream 16 communities (in positive or negative ways) (Barbarossa et al. 2020; Moran et al. 2018). Displacement 17 as well as resettlement schemes can have both socio-economic and environmental consequences 18 including those associated with establishment of new agricultural land (Nguyen et al. 2017; Ahsan and 19 Ahmad 2016). Dam construction may also stimulate migration into the affected region, which can lead 20 to deforestation and other negative impacts (Chen et al. 2015). Impacts can be mitigated through basin- 21 scale dam planning that considers GHG emissions along with social and ecological effects (Almeida et 22 al. 2019). Land occupation is minimal for run-of-river hydropower installations, but without storage 23 they have no resilience to drought and installations inhibit dispersal and migration of organisms (Lange 24 et al. 2018). Reservoir hydropower schemes can regulate water flows and reduce flood damage to 25 agricultural production (Amjath-Babu et al. 2019). On the other hand, severe flooding due to failure of 26 hydropower dams has caused fatalities, damage to infrastructure and loss of productive land (Lu et al. | Heritage | 2087 - 2087 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 16 Integrative spatial planning can integrate renewable energy with not just agriculture, but mobility and 17 housing (Hurlbert et al. 2019). Integrated planning is needed to avoid scalar pitfalls, and local and 18 regional contextualised governance solutions need to be sited within a planetary frame of reference 19 (Biermann et al. 2016). Greater planning and coordination are also needed to ensure co-benefits from 20 land-based mitigation (see Box 12.3) as well as from CDR and efforts to reduce food systems emissions. | Heritage | 2088 - 2088 |
| IPCC | IPCC_AR6_WGIII_Full_Report | {12.5.3} Solar panels Land use competition {12.5.3} Integration with buildings and other infrastructure. integration with food production is being explored {12.5.2} Enhanced weathering Disturbance at sites of extraction; Ineffective in low rainfall regions {12.3.1.2} Increase crop yields and biomass production through nutrient supply and increasing pH of acid soils; synergies with biochar {12.5.3} Bio-based options that may displace existing food production A/R Land use competition, potentially leading to indirect land use change; reduced water availability; loss of biodiversity {12.5.3} Strategic siting to minimise adverse impacts on hydrology, land use, biodiversity {12.5.3} Biomass crops Land use competition, potentially leading to indirect land use change; reduced water availability; reduced soil fertility; loss of biodiversity {12.5.3} Strategic siting to minimise adverse impacts / enhance beneficial effects on land use, landscape variability, biodiversity, soil organic matter, hydrology and water quality {12.5.3} Bio-based options that can (to a varying degree) be combined with food production ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Draft Chapter 12 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 12-111 Total pages: 220 Agroforestry Competition with adjacent crops and pastures reduces yields {7.4.3.3} Shelter for stock and crops, diversification, biomass production, increases soil organic matter and soil fertility. Increased biodiversity and perennial vegetation enhance beneficial organisms; can reduce need for pesticides {7.4.3.3, 12.5.3} Soil carbon management in croplands and grasslands Increase in nitrous oxide emissions if fertiliser used to enhance crop production; Reduced cereal production through increased crop legumes and pasture phases could lead to indirect land use change {7.4.3.1, 7.4.3.6} Increasing soil organic matter improves soil health, increases crop and pasture yields, and resilience to drought, can reduce fertiliser requirement, nutrient leaching and need for land use change. | Heritage | 2091 - 2092 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 7 A range of examples of where mitigation measures result in cross-sectoral interactions and integration 8 is identified. The mitigation potential of electric vehicles, including plug-in hybrid hybrids, is linked to 9 the extent of decarbonisation of the electricity grid, as well as to the liquid fuel supply emissions profile 10 (Lutsey 2015). Making buildings energy positive, where excess energy is used to charge vehicles, can 11 increase the potential of electric and hybrid vehicles (Zhou et al. 2019). Advanced process control and 12 process optimisation in industry can reduce energy demand and material inputs (Section 11.3), which 13 in turn can reduce emissions linked to resource extraction and manufacturing. Reductions in coal-fired 14 power generation through replacement with renewables or nuclear power result in a reduction in coal 15 mining and its associated emissions. Increased recycling results in a reduction in emissions from 16 primary resource extraction. CCU can contribute to the transition to more renewable energy systems 17 via power-to-X technologies, which enables the production of CO2-based fuels/e-fuels and chemicals 18 using carbon dioxide and hydrogen ( Breyer et al. 2015; Anwar et al. 2020). Certain reductions in the 19 AFOLU sector are contingent on energy sector decarbonisation. Trees and green roofs planted to 20 counter urban heat islands reduce the demand for energy for air conditioning and simultaneously 21 sequester GHGs (Kim and Coseo 2018; Kuronuma et al. 2018). Recycling of organic waste avoids 22 methane generation if the waste would have been disposed of in landfill sites, can generate renewable 23 energy if treated through anaerobic digestion and can reduce requirements for synthetic fertiliser 24 production if the nutrient value is recovered (Creutzig et al. 2015). Liquid transport biofuels links to the 25 land, energy and transport sectors (Section 12.5.2.2). | Heritage | 2101 - 2101 |

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| IPCC | IPCC_AR6_WGIII_Full_Report | 35 Moreover, deep mitigation requires moving beyond existing technological responses (Mulugetta and Castán 36 Broto 2018) to policies that correspond to the realities of developing countries (Bouteligier 2013). However, 37 best practice approaches tend to be fragmented due to the requirements of different contexts, and often 38 executed as pilot projects that rarely lead to structural change (Nagorny-Koring 2019). Instead, context- 39 specific approaches that include consideration of values, cultures and governance better enable successful 40 translation of best practices (Affolderbach and Schulz 2016; Urpelainen 2018). | Heritage | 2222 - 2222 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 8 Significant variation in ideas, values and beliefs related to climate governance are detected across and within 9 regions, countries, societies, organisations, and individuals (Shwom et al. 2015; Boasson et al. 2021; Knox- 10 Hayes 2016; Wettestad and Gulbrandsen 2018) (medium evidence, medium agreement). These factors 11 provide the context for climate policymaking and include differences in countries' histories (Aamodt 2018; 12 Aamodt and Boasson 2020); the political culture and regulatory traditions in governing environmental and 13 energy issues (Tosun 2018; Aamodt 2018; Boasson et al. 2021); and even bureaucrats' educational 14 background (Rickards et al. 2014). Structural factors in a country, such as deeply held value systems, are not 15 changed rapidly, just as political systems or natural endowments, are not changed rapidly. Consequently 16 climate policy and governance is more effective if it takes into account these deep-rooted values and beliefs. | Heritage | 2226 - 2226 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 39 This is not surprising, given that courts play differing roles across varying political systems and law traditions 40 (La Porta et al. 1998). | Heritage | 2230 - 2230 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 8 Overall, courts have also played a more active role for climate governance in democratic political systems 9 (Peel and Osofsky 2015; Eskander et al. 2021), but recently legal reforms have also developed in other 10 countries, such as the environmental public interest law in China that allows individuals and groups to initiate 11 environmental litigation (Xie and Xu 2021; Zhao et al. 2019). Whether and to what extent differing law 12 traditions and political systems influence the role and importance of climate litigation has, however, not been 13 examined enough scientifically (Peel and Osofsky 2020; Setzer and Vanhala 2019). | Heritage | 2231 - 2231 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 3 4 13.4.3 Media as communicative platforms for shaping climate governance 5 Media is another platform for various actors to present, interpret and shape debates around climate change 6 and its governance (Tindall et al. 2018). The media coverage of climate change has grown steadily since 7 1980's (O'Neill et al. 2015; Boykoff et al. 2019), but the level and type of coverage differs over time and 8 from country to country (Boykoff 2011; Schmidt et al. 2013; Schäfer and Schlichting 2014) (robust evidence, 9 high agreement). Media can be a useful conduit to build public support to accelerate mitigation action, but 10 may also be utilized to impede decarbonisation endeavours (Farrell 2016b; Carmichael et al. 2017; 11 Carmichael and Brulle 2018; Boykoff 2011; O'Neill et al. 2015). Different media systems in different regions 12 and countries and with unique cultural and political traditions also affect how climate change is 13 communicated (Eskjær 2013). | Heritage | 2233 - 2233 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 21 Popular culture images, science fictions and films of ecological catastrophe can dramatically and emotively 22 convey the dangers of climate change (Bulfin 2017). The overall accuracy of the media coverage on climate 23 change has improved from 2005 to 2019 in the United Kingdom (UK), Australia, New Zealand, Canada, and 24 the US (McAllister et al. 2021). Moreover, coverage of climate science is increasing. One study (MeCCO) 25 has tracked media coverage of climate change from over 127 sources from 59 countries in North and Latin 26 America, Europe, Middle East, Africa, Asia and Oceania (Boykoff et al. 2021). It shows the number of media 27 science stories in those sources grew steadily from 47376 per annum to 86587 per annum between 2017 and 28 2021 across print, broadcast, digital media and entertainment (Boykoff et al. 2021). | Heritage | 2233 - 2233 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 31 Experiments span smart technologies (e.g., in Malmö, Sweden (Parks 2019), Eco-Art, Transformation-Labs 32 and other approaches that question the cultural basis of current energy regimes and seek reimagined or 33 reinvented futures (Guy et al. 2015; Voytenko et al. 2016; Hodson et al. 2018; Peng and Bai 2018; Culwick 34 et al. 2019; Pereira et al. 2019; Sengers et al. 2019; Castán Broto and Bulkeley 2013; Smeds and Acuto 35 2018). They may include governance experiments, from formally defined policy experiments to informal 36 initiatives that mobilise new governance concepts (Kivimaa et al. 2017a; Turnheim et al. 2018), and co- 37 design initiatives and grassroots innovations (Martiskainen 2017; Sheikh and Bhaduri 2021). These 38 initiatives often expand the scope for citizen participation. For example, Urban Living Labs foster 39 innovation, coproducing responses to existing problems of energy use, energy poverty and mobility that 40 integrate scientific and expert knowledge with local knowledge and common values (Voytenko et al. 2016; 41 Marvin et al. 2018). The European Network of Living Labs- with a global outreach- has established a model 42 of open and citizen-centric innovation for policy making. The proliferation of Climate Assemblies at the 43 national and sub-national level further emphasises the increasing role that citizens can play in both innovating 44 and planning for carbon mitigation (Sandover et al. 2021). | Heritage | 2237 - 2237 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 32 Energy efficiency labelling is in widespread use, including for buildings, and for end users products including 33 cars and appliances. Carbon labelling is used for example for food (Camilleri et al. 2019) and tourism 34 (Gössling and Buckley 2016). Information measures also include specific information systems such as smart 35 electricity meters (Zangheri et al. 2019). Chapters 5 and 9 provide detail. | Heritage | 2253 - 2253 |

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| IPCC | IPCC_AR6_WGIII_Full_Report | 11 In practice, integration has to occur in the context of an already existing policy structure, which suggests the 12 need for finding windows of opportunity to bring about integration, which can be created by international 13 events, alignments with domestic institutional procedures, and openings created by policy entrepreneurs 14 (Garcia Hernandez and Bolwig 2020). Integration also has to occur in the context of existing organisational 15 routines and cultures, which can pose a barrier to integration (Uittenbroek 2016). Experience from the EU 16 suggests that disagreements at the level of policy instruments are amenable to resolution by deliberation, 17 while normative disagreements at the level of objectives require a hierarchical decision structure (Skovgaard 18 2018). As this discussion suggests, the challenge of integration operates in two dimensions: horizontal -- 19 between sectoral authorities such as ministries or policy domains such as forestry -- or vertical -- either 20 between constitutional levels of power or within the internal mandates and interactions of a sector (Howlett 21 and del Rio 2015; Di Gregorio et al. 2017). There are also important temporal dimensions to policy goals, as 22 policy and benchmarks have to address not just immediate success but also indications of future 23 transformation (Dupont and Oberthür 2012; Dupont 2015). | Heritage | 2264 - 2264 |
| IPCC | IPCC_AR6_WGIII_Full_Report | Co-benefits generated by climate actions at cities: heat stress reduction; water scarcity, stormwater and flood management; air quality improvement, human health and well being, aesthetic/ amenity, recreation / tourism, environmental justice, real estate value, food production, green jobs opportunities. | Heritage | 2273 - 2273 |
| IPCC | IPCC_AR6_WGIII_Full_Report | • Carbon storage and sequestration • Reduced energy consumption Adaptation benefits: flood management, heat stress reduction individually, or jointly, coastal protection, water scarcity management, groundwater resources, ecosystem resilience improvement, air quality, water supply, flood control, water quality improvement, groundwater recharge. Social co-benefits: aesthetic, recreation, environmental education, improved human health/wellbeing, social cohesion, and poverty reduction. Policy examples: National building code guidelines, flood safety standards, local land-use plans, local building codes, integrated water management for flood control, (Atchison 2019; Conger and Chang 2019; Schoonees et al. 2019; De la Sota et al. 2019; Choi et al. 2021; Zwierzchowska et al. 2019) REDD+ Strategies; An incentive for developing countries to increase carbon sinks, to protect their forest resources and coastal wetlands. Mostly are national strategies led by the state with contribution of international donors. | Heritage | 2273 - 2273 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 17 Justice principles are rarely incorporated in climate change framing and action (Sovacool and Dworkin 2015; 18 Genus and Theobald 2016; Heikkinen et al. 2019; Romero-Lankao and Gnatz 2019). Yet, equity is salient to 19 mitigation debates, because climate change mitigation policies can have also negative impacts (Brugnach et 20 al. 2017; Ramos-Castillo et al. 2017; Klinsky 2018), exacerbated by poverty, inequality and corruption 21 (Markkanen and Anger-Kraavi 2019; Reckien et al. 2018). The siting of facilities and infrastructure that 22 advance decarbonisation (such as public transit infrastructure, renewable energy facilities etc.) may have 23 implications for environmental justice. Integrated attention to justice in climate, environment and energy, as 24 well as involvement of host communities in siting assessments and decision-making processes, can help to 25 avoid such conflict (McCord et al. 2020; Hughes and Hoffmann 2020). As a result, successful policy 26 integration goes beyond optimizing public management routines, and must resolve key trade-offs between 27 actors and objectives (Meadowcroft 2009; Nordbeck and Steurer 2016). | Heritage | 2276 - 2276 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 13 Becken (2019) argues that only systemic changes at a large scale will be sufficient to break or disrupt existing 14 arrangements and routines in the tourism industry 15 Others argue for thinking about mitigation in even wider ways. O'Brien (2018) posits that sector-focused, or 16 a silo approach, to mitigation may need to give way to decisions and policies which reach across sectoral, 17 geographic and political boundaries and involve a broad set of interrelated processes – practical, political 18 and personal. Gillard et al. (Gillard et al. 2016) argue that a response to climate change has to move beyond 19 incremental responses, aiming instead for a society wide transformation which goes beyond a system 20 perspective to include learning from social theory; while Eyre et al. (2018) argue that moving beyond 21 incremental emissions reductions will require expanding the focus of efforts beyond the technical to include 22 people, and their behaviour and attitudes. Stoddard et al. (2021) argue that 'more sustainable and just futures 23 require a radical reconfiguration of long-run socio-cultural and political economic norms and institutions'. | Heritage | 2280 - 2280 |
| IPCC | IPCC_AR6_WGIII_Full_Report | Potential (e.g., US) withdrawal further reduces these chances considerably 1 2 In a dynamic context, the literature on climate clubs highlights the co-called 'building blocks' approach 3 (Stewart et al. 2013a,b, 2017). This is a bottom-up strategy designed to create an array of smaller-scale, 4 specialised initiatives for transnational cooperation in particular sectors and/or geographic areas with a 5 wide range of participants. As part of this literature, Potoski and Prakash (2013) provide a conceptual 6 overview of voluntary environmental clubs, showing that many climate clubs do not require demanding 7 obligations for membership and that a substantial segment thereof are mostly informational (Weischer 8 et al. 2012; Andresen 2014). Also crafted onto the building blocks approach, Potoski (2017) 9 demonstrates the theoretical potential for green certification and green technology clubs. Green (2017) 10 further highlights the potential of "pseudo-clubs" with fluid membership and limited member benefits 11 to promote the diffusion and uptake of mitigation standards. Falkner et al. (2021) suggest a typology of 12 normative, bargaining, and transformational clubs. Before the adoption of the Paris Agreement, some 13 literature suggested that the emergence of climate clubs in parallel to the multilateral climate regime 14 would lead to "forum shopping", with states choosing the governance arrangement that best suits their 15 interests (McGee and Taplin 2006; van Asselt 2007; Biermann et al. 2009; Oh and Matsuoka 2017). | Heritage | 2372 - 2372 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 17 The Kyoto Protocol specifies GHG emissions reduction targets for the 2008-2012 commitment period 18 for countries listed in its Annex B (which broadly corresponds to Annex I to the UNFCCC) (UNFCCC 19 1997, Art. 3 and Annex B). The Kyoto Protocol entered into force in 2005. Shortly thereafter, states 20 began negotiating a second commitment period under the Protocol for Annex B parties, as well as 21 initiated a process under the UNFCCC to consider long-term cooperation among all parties. | Heritage | 2375 - 2375 |

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| IPCC | IPCC_AR6_WGIII_Full_ Report | 8 Figure 14.1 illustrates graphically the key features of the Paris Agreement. The Paris Agreement is 9 based on a set of binding procedural obligations requiring parties to 'prepare, communicate, and 10 maintain' 'nationally determined contributions' (NDCs) (UNFCCC 2015a, Art. 4.2) every five years 11 (UNFCCC 2015a, Art. 4.9). These obligations are complemented by: (1) an 'ambition cycle' that 12 expects parties, informed by five-yearly global stocktakes (Art 14), to submit successive NDCs 13 representing a progression on their previous NDCs (UNFCCC 2015a; Bodansky et al. 2017b), and (2) 14 an 'enhanced transparency framework' that places extensive informational demands on parties, tailored 15 to capacities, and establishes review processes to enable tracking of progress towards achievement of 16 NDCs (Oberthür and Bodle 2016). In contrast to the Kyoto Protocol with its internationally inscribed 17 targets and timetable for emissions reduction for developed countries, the Paris Agreement contains 18 nationally determined contributions embedded in an international system of transparency and 19 accountability for all countries (Doelle 2016; Maljean-Dubois and Wemaëre 2016) accompanied by a 20 shared global goal, in particular in relation to a temperature limit. | Heritage | 2381 - 2381 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | 21 14.3.2.1 Context and purpose 22 The preamble of the Paris Agreement lists several factors that provide the interpretative context for the 23 Agreement (Carazo 2017; Bodansky et al. 2017b), including a reference to human rights. The human 24 rights implications of climate impacts garnered particular attention in the lead up to Paris (Duyck 2015; 25 Mayer 2016b). In particular, the Human Rights Council, its special procedures mechanisms, and the 26 Office of the High Commissioner for Human Rights, through a series of resolutions, reports, and 27 activities, advocated a rights-based approach to climate impacts, and sought to integrate this approach 28 in the climate change regime. The Paris Agreement's preambular recital on human rights recommends 29 that parties, 'when taking action to address human rights', take into account 'their respective obligations 30 on human rights' (UNFCCC 2015a, preambular recital 14), a first for an environmental treaty (Knox 31 2016). The 'respective obligations' referred to in the Paris Agreement could potentially include those ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 14 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 14-21 Total pages: 155 1 relating to the right to life (UNGA 1948, Art. 3, 1966, Art. 6), right to health (UNGA 1966b, Art. 12), 2 right to development, right to an adequate standard of living, including the right to food (UNGA 1966b, 3 Art. 11), which has been read to include the right to water and sanitation (CESCR 2002, 2010), the right 4 to housing (CESCR 1991), and the right to self-determination, including as applied in the context of 5 indigenous peoples (UNGA 1966a,b, Art. 1). In addition, climate impacts contribute to displacement 6 and migration (Mayer and Crépeau 2016; McAdam 2016), and have disproportionate effects on women 7 (Pearse 2017). There are differing views on the value and operational impact of the human rights recital 8 in the Paris Agreement (Adelman 2018; Boyle 2018; Duyck et al. 2018; Rajamani 2018; Savaresi 2018; 9 Knox 2019). Notwithstanding proposals from some parties and stakeholders to mainstream and 10 operationalise human rights in the climate regime post-Paris (Duyck et al. 2018), and references to 11 human rights in COP decisions, the 2018 Paris Rulebook contains limited and guarded references to 12 human rights (Duyck 2019; Rajamani 2019) (see Section 14.5.1.2). In addition to the reference to human 13 rights, the preamble also notes the importance of 'ensuring the integrity of all ecosystems, including 14 oceans and the protection of biodiversity' which provides opportunities for integrating and 15 mainstreaming other environmental protections. | Heritage | 2381 - 2382 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | 16 The overall purpose of international cooperation through the Paris Agreement is to enhance the 17 implementation of the UNFCCC, including its objective of stabilising atmospheric GHG concentrations 18 'at a level that would prevent dangerous anthropogenic interference with the climate system' (UNFCCC 19 1992, Art. 2). The Paris Agreement aims to strengthen the global response to the threat of climate 20 change, in the context of sustainable development and efforts to eradicate poverty, by inter alia 21 '[h]olding the increase in the global average temperature to well below 2°C above pre-industrial levels 22 and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels' (UNFCCC 23 2015a, Art. 2(1)(a)). There is an ongoing structured expert dialogue under the UNFCCC in the context 24 of the second periodic review of the long-term global goal (the first was held between 2013-2015) aimed 25 at enhancing understanding of the long-term global goal, pathways to achieving it, and assessing the 26 aggregate effect of steps taken by parties to achieve the goal. | Heritage | 2382 - 2382 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | 36 As the risks of adverse climate impacts, even with a 'well below' 2°C increase, are substantial, the 37 purpose of the Paris Agreement extends to increasing adaptive capacity and fostering climate resilience 38 (UNFCCC 2015a, Art. 2(1)(b)), as well as redirecting investment and finance flows (UNFCCC 2015a, 39 Art (2)(1)(c); Thorgeirsson 2017). The finance and adaptation goals are not quantified in the Paris 40 Agreement itself but the temperature goal and the pathways they generate may, some argue, enable a 41 quantitative assessment of the resources necessary to reach these goals, and the nature of the impacts 42 requiring adaptation (Rajamani and Werksman 2018). The decision accompanying the Paris Agreement 43 resolves to set a new collective quantified finance goal prior to 2025 (not explicitly limited to developed countries), with USD100 billion yr-1 44 as a floor (UNFCCC 2016a, para. 53; Bodansky et al. 2017b). | Heritage | 2382 - 2382 |

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| IPCC | IPCC_AR6_WGIII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS Final Government Distribution Chapter 14 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 14-22 Total pages: 155 1 The Paris Agreement's purpose is accompanied by an expectation that the Agreement 'will be' 2 implemented to 'reflect equity and the principle of common but differentiated responsibilities and 3 respective capabilities (CBDRRC), in the light of different national circumstances' (UNFCCC 2015a, 4 Art. 2.2). This provision generates an expectation that parties will implement the agreement to reflect 5 CBDRRC, and is not an obligation to do so (Rajamani 2016a). Further, the inclusion of the term 'in 6 light of different national circumstances' introduces a dynamic element into the interpretation of the 7 CBDRRC principle. As national circumstances evolve, the application of the principle will also evolve 8 (Rajamani 2016a). This change in the articulation of the CBDRRC principle is reflected in the shifts in 9 the nature and extent of differentiation in the climate change regime (Maljean-Dubois 2016; Rajamani 10 2016a; Voigt and Ferreira 2016a), including through a shift towards 'procedurally-oriented 11 differentiation' for developing countries (Huggins and Karim 2016). | Heritage | 2382 - 2383 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 12 Although NDCs are developed by individual state parties, the Paris Agreement requires that these are 13 undertaken by parties 'with a view' to achieving the Agreement's purpose and collectively 'represent a 14 progression over time' (UNFCCC 2015a, Art. 3). The Paris Agreement also encourages parties to align 15 the ambition of their NDCs with the temperature goal through the Agreement's 'ambition cycle', thus 16 imparting operational relevance to the temperature goal (Rajamani and Werksman 2018). | Heritage | 2383 - 2383 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 18 14.3.2.2 NDCs, progression and ambition 19 Each party to the Paris Agreement has a procedural obligation to 'prepare, communicate and maintain' 20 successive NDCs 'that it intends to achieve.' Parties have a further procedural obligation to 'pursue 21 domestic mitigation measures' (UNFCCC 2015a, Art. 4.2). These procedural obligations are coupled 22 with an obligation of conduct to make best efforts to achieve the objectives of NDCs (Rajamani 2016a; 23 Mayer 2018b). Many states have adopted climate policies and laws, discussed in Chapter 13, and 24 captured in databases (LSE 2020). | Heritage | 2384 - 2384 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 25 The framing and content of NDCs is thus largely left up to parties, although certain normative 26 expectations apply. These include developed country leadership through these parties undertaking 27 economy-wide absolute emissions reduction targets (UNFCCC 2015a, Art. 4.4), as well as 28 'progression' and 'highest possible ambition' reflecting 'common but differentiated responsibilities and 29 respective capabilities in light of different national circumstances' (Art 4.3). There is 'a firm 30 expectation' that for every five-year cycle a party puts forward a new or updated NDC that is 'more 31 ambitious than their last' (Rajamani 2016a). While what represents a party's highest possible ambition 32 and progression is not prescribed by the Agreement or elaborated in the Paris Rulebook (Rajamani and 33 Bodansky 2019), these obligations could be read to imply a due diligence standard (Voigt and Ferreira 34 2016b). | Heritage | 2384 - 2384 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 35 In communicating their NDCs every five years (UNFCCC 2015a, Art. 4.9), all parties have an 36 obligation to 'provide the information necessary for clarity, transparency and understanding' (UNFCCC 37 2015a, Art. 4.8). These requirements are further elaborated in the Paris Rulebook (Doelle 2019; 38 UNFCCC 2019b). This includes requirements — for parties' second and subsequent NDCs — to 39 provide quantifiable information on the reference point e.g. base year, reference indicators and target 40 relative to the reference indicator (UNFCCC 2019b, Annex I, para 1). It also requires parties to provide 41 information on how they consider their contribution 'fair and ambitious in light of different national 42 circumstances', and how they address the normative expectations of developed country leadership, 43 progression and highest possible ambition (UNFCCC 2019b, Annex I, para 6). However, parties are 44 required to provide the enumerated information only 'as applicable' to their NDC (UNFCCC 2019b, 45 Annex I, para 7). This allows parties to determine the informational requirements placed on them 46 through their choice of NDC. In respect of parties' first NDCs or NDCs updated by 2020, such 47 quantifiable information 'may' be included, 'as appropriate', signalling a softer requirement, although 48 parties are 'strongly encouraged' to provide this information (UNFCCC 2019b, Annex I, para 9). | Heritage | 2384 - 2384 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 3 4 14.3.2.3 NDCs, fairness and equity 5 The Paris Agreement encourages Parties, while submitting their NDCs, to explain how these are 'fair 6 and ambitious' (UNFCCC 2015a, Art. 4.8 read with UNFCCC 2016a, para. 27). The Rulebook obliges 7 Parties to provide information on 'fairness considerations, including reflecting on equity' as applicable 8 to their NDC (Rajamani and Bodansky 2019; UNFCCC 2019b paras 7a and 9, Annex, paras 6(a) and 9 (b)). Although equity within nations and between communities is also important, much of the literature 10 on fairness and equity in the context of NDCs focuses on equity between nations. | Heritage | 2387 - 2387 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 25 14.3.2.4 Transparency and accountability 26 Although NDCs reflect a 'bottom-up', self-differentiated approach to climate mitigation actions, the 27 Paris Agreement couples this to an international transparency framework designed, among other things, 28 to track progress in implementing and achieving mitigation contributions (UNFCCC 2015a, Art. 13). | Heritage | 2388 - 2388 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 29 This transparency framework builds on the processes that already exist under the UNFCCC. The 30 transparency framework under the Paris Agreement s applicable to all Parties, although with flexibilities 31 for developing country Parties that need it in light of their capacities (Mayer 2019). Each Party is 32 required to submit a national inventory report, as well as 'the information necessary to track progress 33 in implementing and achieving' its NDC, (UNFCCC 2015a, Art. 13.7) biennially (UNFCCC 2016a, 34 para. 90). The Paris Rulebook requires all Parties to submit their national inventory reports using the 35 2006 IPCC Guidelines (UNFCCC 2019b, Annex, para. 20). | Heritage | 2388 - 2388 |

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| IPCC | IPCC_AR6_WGIII_Full_Report | 36 In relation to the provision of information necessary to track progress towards implementation and 37 achievement of NDCs, the Paris Rulebook allows each party to choose its own qualitative or 38 quantitative indicators (UNFCCC 2019k, Annex, para 65), a significant concession to national 39 sovereignty (Rajamani and Bodansky 2019). The Rulebook phases in common reporting requirements 40 for developed and developing countries (except LDCs and SIDS) at the latest by 2024 (UNFCCC 41 2019k, para. 3), but offers flexibilities in 'scope, frequency, and level of detail of reporting, and in the 42 scope of the review' for those developing countries that need it in light of their capacities (UNFCCC 43 2019k, Annex, para. 5). Some differentiation also remains for information on support provided to 44 developing countries (Winkler et al. 2017), with developed country parties required to report such 45 information biennially, while others are only 'encouraged' to do so (UNFCCC 2015a, Art. 9.7). | Heritage | 2388 - 2388 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 18 14.3.2.5 Global stocktake 19 The Paris Agreement's transparency framework is complemented by the global stocktake, which will 20 take place every five years (starting in 2023) and assess the collective progress towards achieving the 21 Agreement's purpose and long-term goals (UNFCCC 2015a, Art. 14). The scope of the global stocktake 22 is comprehensive – covering mitigation, adaptation and means of implementation and support – and the 23 process is to be facilitative and consultative. The Paris Rulebook outlines the scope of the global 24 stocktake to include social and economic consequences and impacts of response measures, and loss and 25 damage associated with the adverse effects of climate change (UNFCCC 2019f, paras. 8-10). | Heritage | 2389 - 2389 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 36 The global stocktake is seen as crucial to encouraging parties to increase the ambition of their NDCs 37 (Huang 2018; Hermwille et al. 2019; Milkoreit and Haapala 2019) as its outcome 'shall inform Parties 38 in updating and enhancing, in a nationally determined manner, their actions and support' (Art 14.3) 39 (Rajamani 2016a; Friedrich 2017; Zahar 2019). The Rulebook provides for the stocktake to draw on a 40 wide variety of inputs sourced from a full range of actors, including 'non-Party stakeholders' (UNFCCC 41 2019f, para. 37). However, the Rulebook specifies that the global stocktake will be 'a Party-driven 42 process' (UNFCCC 2019f, para. 10), will not have an 'individual Party focus', and will include only 43 'non-policy prescriptive consideration of collective progress' (UNFCCC 2019f, para. 14). | Heritage | 2389 - 2389 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 45 14.3.2.8 Finance flows 46 Finance is the first of three means of support specified under the Paris Agreement to accomplish its 47 objectives relating to mitigation (and adaptation) (UNFCCC 2015a, Art. 14.1). This sub-section 48 discusses the provision made in the Paris Agreement for international cooperation on finance. Section ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 14 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 14-31 Total pages: 155 1 14.4.1 below considers broader cooperative efforts on public and private finance flows for climate 2 mitigation, including by multilateral development banks and through instruments such as green bonds. | Heritage | 2391 - 2392 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 3 As highlighted above, the objective of the Paris Agreement includes the goal of '[m]aking finance flows 4 consistent with a pathway towards low greenhouse gas emissions and climate-resilient development' 5 (UNFCCC 2015a, Art 2.1(c)). Alignment of financial flows, and in some cases provision of finance 6 will be critical to the achievement of many parties' NDCs, particularly those that are framed in 7 conditional terms (Zhang and Pan 2016; Kissinger et al. 2019) (see further Chapter 15 on investment 8 and finance). | Heritage | 2392 - 2392 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 27 Much of the current literature on climate finance and the Paris Agreement focuses on the obligations of 28 developed countries to provide climate finance to assist the implementation of mitigation and adaptation 29 actions by developing countries. The principal provision on finance in the Paris Agreement is the 30 binding obligation on developed country parties to provide financial resources to assist developing 31 country parties (UNFCCC 2015a, Art 9.1). This provision applies to both mitigation and adaptation and 32 is in continuation of existing developed country parties' obligations under the UNFCCC. This signals 33 that the Paris Agreement finance requirements must be interpreted in light of the UNFCCC (Yamineva 34 2016). The novelty introduced by the Paris Agreement is a further expansion in the potential pool of 35 donor countries as Article 9.2 encourages 'other parties' to provide or continue to provide such support 36 on a voluntary basis. However, 'as part of the global effort, developed countries should continue to take 37 the lead in mobilising climate finance', with a 'significant role' for public funds, and an expectation 38 that such mobilisation of finance 'should represent a progression beyond previous efforts' Beyond this 39 there are no new recognised promises (Ciplet et al. 2018). In the Paris Agreement parties formalized 40 the continuation of the existing collective mobilization goal to raise 100 billion a year through 2025 in 41 the context of meaningful mitigation actions and transparency on implementation. The Paris Agreement 42 decision also provided for the CMA by 2025 to set a new collective quantified goal from a floor of USD100 billion yr- 43 , taking into account the needs and priorities of developing countries (UNFCCC 44 2016a, para. 53). This new collective goal on finance is not explicitly limited to developed countries 45 and could therefore encompass finance flows from developing countries' donors (Bodansky et al. | Heritage | 2392 - 2392 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 33 14.3.2.9 Technology development and transfer 34 Technology development and transfer is the second of three 'means of implementation and support' 35 specified under the Paris Agreement to accomplish its objectives relating to mitigation (and adaptation) 36 (UNFCCC 2015a, Art. 14.1). This sub-section discusses the provision made in the Paris Agreement for 37 international cooperation on technology development and transfer. Section 14.4.2 below considers 38 broader cooperative efforts on technology development and transfer under the UNFCCC. Both sections 39 complement the discussion in Chapter 16.6 on the role of international cooperation in fostering 40 transformative change. | Heritage | 2393 - 2393 |

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| IPCC | IPCC_AR6_WGIII_Full_Report | 6 Article 10 of the Paris Agreement articulates a shared 'long-term vision on the importance of fully 7 realising technology development and transfer in order to improve resilience to climate change and to 8 reduce greenhouse gas emissions' (UNFCCC, 2015, Art. 10.1). All parties are required 'to strengthen 9 cooperative action on technology development and transfer' (UNFCCC, 2015, Art. 10.2). In addition, 10 support, including financial support, 'shall be provided' to developing country parties for the 11 implementation of Article 10, 'including for strengthening cooperative action on technology 12 development and transfer at different stages of the technology cycle, with a view to achieving a balance 13 between support for mitigation and adaptation' (UNFCCC, 2015, Art. 10.6). Available information on 14 efforts related to support on technology development and transfer for developing country parties is also 15 one of the matters to be taken into account in the global stocktake (UNFCCC, 2015, Art. 10.6) (see 16 Section 14.3.2.5 above). | Heritage | 2394 - 2394 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 17 The Paris Agreement emphasises that efforts to accelerate, encourage and enable innovation are 'critical 18 for an effective long-term global response to climate change and promoting economic growth and 19 sustainable development' and urges that they be supported, as appropriate, by the Technology 20 Mechanism and Financial Mechanism of the UNFCCC (UNFCCC, 2015, Art. 10.5). This support 21 should be directed to developing country parties 'for collaborative approaches to research and 22 development, and facilitating access to technology, in particular for early stages of the technology cycle' 23 (UNFCCC, 2015, Art. 10.5). Inadequate support for R&D, particularly in developing countries, has 24 been identified in previous studies of technology interventions by international institutions as a key 25 technology innovation gap that might be addressed by the Technology Mechanism (Coninck and Puig 26 2015). | Heritage | 2394 - 2394 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 27 To support parties' cooperative action, the Technology Mechanism, established in 2010 under the 28 UNFCCC (see further Section 14.4.2 below), will serve the Paris Agreement, subject to guidance of a 29 new 'technology framework' (UNFCCC, 2015, Art. 10.4). The latter was strongly advocated by the 30 African group in the negotiations for the Paris Agreement (Oh 2020a), and was adopted in 2018 as part 31 of the Paris Rulebook, with implementation entrusted to the component bodies of the Technology 32 Mechanism. The guiding principles of the framework are coherence, inclusiveness, a results-oriented 33 approach, a transformational approach and transparency. Its 'key themes' include innovation, 34 implementation, enabling environment and capacity-building, collaboration and stakeholder 35 engagement, and support (UNFCCC 2019e, Annex). A number of 'actions and activities' are elaborated 36 for each thematic area. These include: enhancing engagement and collaboration with relevant 37 stakeholders, including local communities and authorities, national planners, the private sector and civil 38 society organisations, in the planning and implementation of Technology Mechanism activities; 39 facilitating parties undertaking, updating and implementing technology needs assessments (TNAs) and 40 aligning these with NDCs; and enhancing the collaboration of the Technology Mechanism with the 41 Financial Mechanism for enhanced support for technology development and transfer. As regards TNAs, 42 while some developing countries have already used the results of their TNA process in NDC 43 development, other countries might benefit from following the TNA process, including its stakeholder 44 involvement, and multi-criteria decision analysis methodology, to strengthen their NDCs (Hofman and 45 van der Gaast 2019). | Heritage | 2394 - 2394 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 46 14.3.2.10Capacity-building 47 Together with finance, and technology development and transfer, capacity-building is the third of 'the 48 means of implementation and support' specified under the Paris Agreement (see UNFCCC 2015a, Art. | Heritage | 2394 - 2394 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 22 The Paris Agreement urges all parties to cooperate to enhance the capacity of developing countries to 23 implement the Agreement (UNFCCC 2015a, Art. 11.3), with a particular focus on LDCs and SIDS 24 (UNFCCC 2015a, Art. 11.1). Developed country parties are specifically urged to enhance support for 25 capacity-building actions in developing country Parties (UNFCCC 2015a, Art. 11.3). Article 12 of the 26 Paris Agreement addresses cooperative measures to enhance climate change education, training, public 27 awareness, public participation and public access to information, which can also be seen as elements of 28 capacity-building (Khan et al. 2020). Under the Paris Rulebook, efforts related to the implementation 29 of Article 12 are referred to as 'Action for Climate Empowerment' and parties are invited to develop 30 and implement national strategies on this topic, taking into account their national circumstances 31 (UNFCCC 2019i, para. 6). Actions to enhance climate change education, training, public awareness, 32 public participation, public access to information, and regional and international cooperation may also 33 be taken into account by parties in the global stocktake process under Article 14 of the Paris Agreement 34 (UNFCCC 2019i, para. 9). | Heritage | 2395 - 2395 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 35 Under the Paris Agreement, capacity-building can take a range of forms, including: facilitating 36 technology development, dissemination and deployment; access to climate finance; education, training 37 and public awareness; and the transparent, timely and accurate communication of information 38 (UNFCCC 2015a, Art. 11.1; see also 14.3.2.4 on 'Transparency' above). Principles guiding capacity- 39 building support are that it should be: country-driven; based on and responsive to national needs; 40 fostering country ownership of parties at multiple levels; guided by lessons learned; and an effective, 41 iterative process that is participatory, cross-cutting and gender-responsive (UNFCCC 2015a, Art. 11.2). | Heritage | 2395 - 2395 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 42 Parties undertaking capacity-building for developing country parties must 'regularly communicate on 43 these actions or measures.' Developing countries parties have a soft requirement ('should') to 44 communicate progress made on implementing capacity-building plans, policies, actions or measures to 45 implement the Paris Agreement (UNFCCC 2015a, Art. 11.4). | Heritage | 2395 - 2395 |

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|---|---|---|---|---|
| IPCC | IPCC_AR6_WGIII_Full_Report | 9 14.4.1 Finance 10 International cooperation on climate finance is underpinned by various articles of the UNFCCC 11 including Articles 4.3, 4.4, 4.5, 4.7 and 11.5 (UNFCCC 1992). This was further amplified through the 12 commitment by developed countries in the Copenhagen Accord and the Cancun Agreements to mobilise jointly through various sources USD100 billion yr-1 13 by 2020 to meet the needs of the developing 14 countries (UNFCCC 2010b). This commitment was made in the context of meaningful mitigation action 15 and transparency of implementation. As mentioned earlier in Section 14.3.2.8, in the Paris Agreement 16 the binding obligation on developed country parties to provide financial resources to assist developing 17 country parties applies to both mitigation and adaptation (UNFCCC 2015a, Art. 9.1). In 2019, climate 18 finance provided and mobilised by developed countries was in the order of USD79.6 billion, coming 19 from different channels including bilateral and multilateral channels, and also through mobilisation of 20 the private sector attributable to these channels (OECD 2021). A majority (two-thirds) of these flows 21 targeted mitigation action exclusively (see also Chapter 15). These estimates, however, have been 22 criticised on various grounds, including that they are an overestimate and do not represent climate 23 specific net assistance only; that in grant equivalence terms the order of magnitude is lower; and the 24 questionable extent of transparency of information on mobilised private finance, as well as the direction 25 of these flows (Carty et al. 2020). On balance, such assessments need to be viewed in the context of the 26 original commitment, the source of the data and the evolving guidance, and modalities and procedures 27 from the UNFCCC processes. As mentioned in Chapter 15, the measurement of climate finance flows 28 continues to face definitional, coverage and reliability issues despite progress made by various data 29 providers and collators (see section 15.3.2 in Chapter 15). | Heritage | 2407 - 2407 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 36 However, there are areas in which international cooperation can be strengthened. Both the Paris 37 Agreement and the 2030 Agenda for Sustainable Development call for more creative forms of 38 international cooperation in science that help bridge the science and policy interface, and provide 39 learning processes and places to deliberate on possible policy pathways across disciplines on a more 40 sustainable and long-lasting basis. Scientific assessments, such as the IPCC and IPBES offer this 41 possibility, but processes need to be enriched for this to happen more effectively (Kowarsch et al. 2016) 42 A particular locus for international cooperation on technology development and innovation is found 43 within institutions and mechanisms of the UN climate regime. The UNFCCC, in Article 4.1(c), calls on 44 'all parties' to 'promote and cooperate in the development, application and diffusion, including transfer, 45 of technologies, practices and processes that control, reduce or prevent anthropogenic emissions of 46 greenhouse gases' and places responsibility on developed country parties to 'take all practicable steps 47 to promote, facilitate and finance, as appropriate, the transfer of, or access to environmentally sound 48 technologies and know-how to other parties, particularly developing country parties, to enable them to ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 14 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 14-52 Total pages: 155 1 implement the provisions of the Convention' (UNFCCC 1992, Art. 4.5). The issue of technology 2 development and transfer has continued to receive much attention in the international climate policy 3 domain since its initial inclusion in the UNFCCC in 1992 – albeit often overshadowed by dominant 4 discourses around market-based mechanisms – and its role in reducing GHG emissions and adapting to 5 the consequences of climate change 'is seen as becoming ever more critical' (de Coninck and Sagar 6 2015a). Milestones in the development of international cooperation on climate technologies under the 7 UNFCCC have included: (1) the development of a technology transfer framework and establishment of 8 the Expert Group on Technology Transfer (EGTT) under the Subsidiary Body for Scientific and 9 Technological Advice (SBSTA) in 2001; (2) recommendations for enhancing the technology transfer 10 framework put forward at the Bali Conference of the Parties in 2007 and creation of the Poznan strategic 11 program on technology transfer under the Global Environmental Facility (GEF); and (3) the 12 establishment of the Technology Mechanism by the Conference of the Parties in 2010 as part of the 13 Cancun Agreements (UNFCCC 2010b). The Technology Mechanism is presently the principal avenue 14 within the UNFCCC for facilitating cooperation on the development and transfer of climate 15 technologies to developing countries (UNFCCC 2015b). As discussed in Section 14.3.2.9 above, the 16 Paris Agreement tasks the Technology Mechanism also to serve the Paris Agreement (UNFCCC 2015b, 17 Art. 10.3). | Heritage | 2412 - 2413 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 27 28 14.4.3 Capacity Building 29 International climate cooperation has long focused on supporting developing countries in building 30 capacity to implement climate mitigation actions. While there is no universally agreed definition of 31 capacity-building and the UNFCCC does not define the term (Khan et al. 2020), elements of capacity- 32 building can be discerned from the Convention's provisions on education and training programmes 33 (UNFCCC 1992, Art. 6), as well as the reference in Article 9(2)(d) of the UNFCCC to the Subsidiary 34 Body for Scientific and Technological Advice (SBSTA) providing support for 'endogenous capacity- 35 building in developing countries.' 36 Capacity-building is generally conceived as taking place at three levels: individual (focused on 37 knowledge, skills and training), organisational/institutional (focusing on organisational performance 38 and institutional cooperation) and systemic (creating enabling environments through regulatory and 39 economic policies (Khan et al. 2020; UNFCCC 2021b). In its annual synthesis report for 2018, the 40 UNFCCC secretariat compiled information submitted by parties on the implementation of capacity- 41 building in developing countries, highlighting cooperative and regional activities on NDCs, including 42 projects to build capacity for implementation, workshops related to transparency under the Paris 43 Agreement and collaboration to provide coaching and training (UNFCCC 2019h). A number of 44 developing country Parties also highlighted their contributions to South–South cooperation (discussed 45 further in Section 14.5.1.4 below), and identified capacity-building projects undertaken with others (e.g. | Heritage | 2414 - 2414 |

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| Organisation | Document | Quotation Content | Codes | Page |
|---|---|---|---|---|
| IPCC | IPCC_AR6_WGIII_Full_Report | 34 More recently, the Lowering Emissions by Accelerating Forest Finance (LEAF) Coalition was 35 established, consisting of the governments of Norway, the UK, and the US and initially nine companies 36 in accelerating REDD+ with a jurisdictional approach. LEAF uses the Architecture for REDD+ 37 Transaction, The REDD+ Environmental Excellence Standard (ART-TREES), is coordinated by 38 Emergent, a non-profit intermediary between tropical countries and the private sector. Three 39 jurisdictions in Brazil and two countries have already submitted concept notes to ART to receive results- 40 based payments. REDD+ initiatives with a jurisdictional approach have also been adopted in various 41 markets, such as the CORSIA (Maguire 2021). In addition to Brazil, Indonesia has attracted significant 42 interest as a host country for REDD+. Indonesia ranks second, after Brazil, as the largest producer of 43 deforestation-related GHG emissions (Zarin et al. 2016), but it has committed to a large reduction of 44 deforestation in its NDC (Government of Indonesia 2016). Australia has collaborated on scientific 45 research and emission reduction monitoring (Tacconi 2017). It took a while, however, before emission 46 reductions were witnessed (Meehan et al. 2019). The expansion of commodity plantations, however, 47 conflict with reduction ambitions (Anderson et al. 2016; Irawan et al. 2019) In addition to 48 implementation at the site and jurisdictional levels, legal enforcement (Tacconi et al. 2019) as well as 49 policy and regulatory reforms (Ekawati et al. 2019) appears to be needed. | Heritage | 2438 - 2438 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 4 Increases in trans-Arctic shipping and tourism activities with sea ice loss are also forecast to have strong 5 regional effects due to ships' gas and particulate emissions (Stephenson et al. 2018). | Heritage | 2443 - 2443 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 6 The Kyoto Protocol required Annex I parties to pursue emissions reductions from aviation and marine 7 bunker fuels by working through IMO and ICAO (UNFCCC 1997, Art. 2.2). Limited progress was 8 made by these organisations on emissions controls in the ensuing decades (Liu 2011b), but greater 9 action was prompted by conclusion of the SDGs and Paris Agreement (Martinez Romera 2016), 10 together with unilateral action, such as the EU's inclusion of aviation emissions in its Emissions Trading 11 Scheme (ETS) (Dobson 2020). | Heritage | 2443 - 2443 |
| IPCC | IPCC_AR6_WGIII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 14 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 14-85 Total pages: 155 1 Climate justice has been variously defined, but centres on addressing the disproportionate impacts of 2 climate change on the most vulnerable populations and calls for community sovereignty and functioning 3 (Schlosberg and Collins 2014; Tramel 2016). Contemporary climate justice groups mobilise multiple 4 strands of environmental justice movements from the Global North and South, as well as from distinct 5 indigenous rights and peasant rights movements, and are organised as a decentralised network of 6 semiautonomous, coordinated units (Claeys and Delgado Pugley 2017; Tormos-Aponte and García- 7 López 2018). The climate justice movement held global days of protest in most of the world's countries 8 in 2014 and 2015, and mobilised another large campaign in 2018 (Almeida 2019). The polycentric 9 arrangement of the global climate movement allows simultaneous influence on multiple sites of climate 10 governance, from the local to the global levels (Tormos-Aponte and García-López 2018). | Heritage | 2445 - 2446 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 32 The Paris Agreement's preamble explicitly recognises the importance of engaging "various actors" in 33 addressing climate change, and the decision adopting the Agreement created the Non-State Actor Zone 34 for Climate Action platform to aid in scaling up these efforts. Specific initiatives have also been taken 35 to facilitate participation of particular groups, such as the UNFCCC's Local Communities and 36 Indigenous Peoples Platform, which commenced work in Katowice in 2019. Climate movements based 37 in the Global South, as well as in Indigenous territories, are playing an increasingly important role in 38 transnational negotiations through networks such as the Indigenous Peoples Platform. These groups 39 highlight the voices and perspectives of communities and peoples particularly affected by climate 40 change. For instance, the Pacific Climate Warriors is a grassroots network of young people from various 41 countries in the Pacific Islands region whose activities focus on resisting narratives of future 42 inevitability of their Pacific homelands disappearing, and re-envisioning islanders as warriors defending 43 rights to homeland and culture (McNamara and Farbotko 2017). Youth global climate activism, 44 particularly involving young Indigenous climate activists, is another notable recent development. | Heritage | 2446 - 2446 |
| IPCC | IPCC_AR6_WGIII_Full_Report | ACCEPTED VERSION SUBJECT TO FINAL EDITS<br>Final Government Distribution Chapter 14 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 14-88 Total pages: 155 1 In the same vein, in 2010 FAO delivered the Framework for Assessing and Monitoring Forest 2 Governance. The Framework draws on several approaches currently in use or under development in 3 major forest governance-related processes and initiatives, including the World Bank's Framework for 4 Forest Governance Reform. The Framework builds on the understanding that governance is both the 5 context and the product of the interaction of a range of actors and stakeholders with diverse interests 6 (FAO 2010). For example, UNFCCC and UN-REDD program focus on REDD+ and UNEP focus on 7 TEEB (a global initiative focusing on the economics of ecosystems and biodiversity) institutional 8 mechanisms have been conceptualized as a 'win-win-win' for mitigating climate, protecting 9 biodiversity and conserving indigenous culture by institutionalizing payments on carbon sequestration 10 and biodiversity conservation values of ecosystems services from global to local communities. These 11 mechanisms include public-private partnership, and non-governmental organization participation. | Heritage | 2448 - 2449 |

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| Organisation | Document | Quotation Content | Codes | Page |
|---|---|---|---|---|
| IPCC | IPCC_AR6_WGIII_Full_Report | 12 13 15.2.3 Impact of COVID-19 pandemic 14 The macroeconomic headwinds have worsened dramatically with the onset of COVID-19. Almost two 15 years after the pandemic started, it is still too uncertain and early to conclude impacts of the pandemic 16 until 2025-2030, especially as they affect climate finance. Multiple waves of the pandemic, new virus 17 mutations, accumulating human toll, and growing vaccine coverage but vastly differing access across 18 developed versus developing regions are evident. They are causing divergent impacts across sectors 19 and countries, which combined with the divergent ability of countries and regions to mount sufficient 20 fiscal and monetary policy actions imply continued high uncertainty on the economic recovery paths 21 from the crisis. The situation remains more precarious in middle and low-income developing countries 22 (IMF 2021a). While recovery is happening, the job losses have been large, poverty rates have climbed, 23 public health systems are suffering long-term consequences, education gains have been set back, public 24 debt levels are higher (5-10% of GDP higher), financial institutions have come under longer-term stress, 25 a larger number of developing countries are facing debt distress, and many key high-contact sectors 26 such as tourism and trade will take time to recover (Eichengreen et al. 2021). The implication is 27 negative headwinds for climate finance with public attention focused on pandemic relief and recovery 28 and limited (and divergent) fiscal headroom for a low carbon transition, with considerable uncertainties 29 ahead (Hepburn et al. 2020b; Maffettone and Oldani 2020; Steffen et al. 2020). | Heritage | 2530 - 2530 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 32 On the one hand, each scenario is associated with a warming path, which in turn, on the basis of the 33 results from WGII, implies certain levels of physical risk (see WGII Chapter 16). However, climate 34 impacts are not accounted for in the scenarios. Moreover, levels of risk may vary with the Reason for 35 Concern (RFC, ibidem) and with the speed in the implementation of adaptation. On the other hand, 36 while mitigation can come with transition risk, in the case of lack of coordination among the actors, as 37 discussed earlier in this section, this is not modelled explicitly in the trajectories, since the financial 38 sector is not represented in underlying models. The scientific state of the art in climate-related financial 39 risk offers an analysis that is not yet comprehensive of both the physical and transition risk dimensions 40 in the same quantitative framework. However, decision makers can follow a mixed approach where 41 they can combine quantitative risk assessment for transition risk with more qualitative risk analysis 42 related to physical risk. | Heritage | 2569 - 2569 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 7 Considering the need for responses to both, short-term liquidity issues and long-term fiscal space, 8 current G20/IMF/World Bank debt service suspension initiatives are focused the liquidity issue rather 9 than underlying problems of more structural nature of many low-income (Fresnillo 2020). In order to 10 ensure fiscal space for climate action in the coming decade a mix between debt relief, deferrals of 11 liabilities, extended debt levels and sustainable lending practices including new solidarity structures 12 need to be considered in addition to higher levels of bilateral and multilateral lending to reduce 13 dependency on capital markets and to bridge the availability of sustainably structured loans for highly 14 vulnerable and indebted countries. More standardised debt-for-climate swaps, a higher share of GDP 15 linked bonds or structures ensuring (partial) debt cancellation in case countries are hit by physical 16 climate change impacts/shocks appear possible. The “hurricane” clause introduced by Grenada, or 17 wider natural disaster clauses provide issuers with an option to defer payments of interest and principal 18 in the event of a qualifying natural disaster and can reduce short-term debt stress (UN AAAA Art. 102) 19 (UN 2015a). A mainstreaming of such clauses has been pushed by various international institutions. | Heritage | 2581 - 2581 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 17 There has also been growing interest in social drivers, motivated by the recognition of social issues, 18 such as unemployment and public health, linked to the deployment of innovative low-carbon 19 technologies (Altantsetseg et al. 2020). Policy and social factors and the diverse trajectories of 20 innovation are influenced by regional and national conditions (Tariq et al. 2017), and such local needs 21 and purposes need to be considered in crafting international policies aimed at fostering the global 22 transition towards increased sustainability (Caravella and Crespi 2020). From this standpoint, a 23 multidimensional, multi-actor systemic innovation approach would be needed to enhance global 24 innovation diffusion (de Jesus and Mendonça 2018), especially if this is to lead to overall sustainability 25 improvements rather than resulting in new sustainability challenges. | Heritage | 2682 - 2682 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 22 23 16.3.1 Frameworks for analysing technological innovation processes 24 The resulting overarching framework that is commonly used in the innovation scholarship and even 25 policy analyses is termed as “innovation system”, where the key constituents of the systems are actors, 26 their interactions, and the institutional landscape, including formal rules, such as laws, and informal 27 restraints, such as culture and codes of conduct, that govern the behaviour of the actors (North 1991). | Heritage | 2702 - 2702 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 5 Systemic failures include infrastructural failures; hard (e.g., laws, regulation) and soft (e.g., culture, 6 social norms) institutional failures; interaction failures (strong and weak network failures); capability 7 failures relating to firms and other actors; lock-in; and directional, reflexivity, and coordination failures 8 (Klein Woolthuis et al. 2005; Chaminade and Esquist 2010; Weber and Rohracher 2012; Wieczorek 9 and Hekkert 2012; Negro et al. 2012). By far most of the literature that unpacks such failures and 10 explores ways to overcome them is on energy-related innovation policy. For example, Table 16.6 11 summarizes a meta-study (Negro et al. 2012) that examined cases of renewable energy technologies 12 trying to disrupt incumbents across a range of countries to understand the roles, and relative importance, 13 of the ‘systemic problems’ highlighted in Section 16.3.1. | Heritage | 2705 - 2705 |

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| Organisation | Document | Quotation Content | Codes | Page |
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| IPCC | IPCC_AR6_WGIII_Full_ Report | 14 END BOX 16.4 HERE 15 16 There are many definitions of policy mixes from various disciplines (Rogge et al. 2017), including 17 environmental economics (Lehmann 2012), policy studies (Kern and Howlett 2009) and innovation 18 studies. Generally speaking, a policy mix can be characterised by a combination of building blocks, 19 namely elements, processes and characteristics, which can be specified using different dimensions 20 (Rogge and Reichardt 2016). Elements include (i) the policy strategy with its objectives and principal 21 plans and (ii) the mix of policy instruments, and (iii) instrument design. The content of these elements 22 is the result of policy processes. Both elements and processes can be described by their characteristics 23 in terms of the consistency of the elements, the coherence of the processes, and the credibility and 24 comprehensiveness of the policy mix in different policy, governance, geography and temporal context 25 (Rogge and Reichardt 2016). Other aspects in the evaluation of policy mixes include framework 26 conditions, the type of policy instrument and the lower level of policy granularity, namely design 27 elements or design features (del Río 2014; del Río and Cerdá 2017). In addition, many have argued the 28 need to craft policies that affect different actors in the transition, some supporting and some 29 'destabilising' (see e.g. Kivimaa and Kern (2016) and Geels (2002)). | Heritage | 2717 - 2717 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | 12 Patent systems aim to promote innovation and economic growth, by stimulating both the creation of 13 new knowledge and diffusion of that knowledge (high evidence, high agreement). National patent 14 systems, as institutions, play a central role in theories on national innovation systems (high evidence, 15 strong agreement). Patent systems are usually instituted to promote innovation and economic growth 16 (Nelson and Mazzoleni 1996; Machlup and Penrose 1950; Encaoua et al. 2006). Some countries 17 explicitly refer to this purpose in their law or legislation – for instance, the US Constitution states the 18 purpose of the US IP rights system to "promote the progress of science and useful arts". Patent systems 19 aim to reach their goals by trying to strike a balance between the creation of new knowledge and 20 diffusion of that knowledge (Scotchmer and Green 1990; Devlin 2010; Anadon et al. 2016b). They 21 promote the creation of new knowledge (e.g. technological inventions) by providing a temporary, 22 exclusive right to the holder of the patent, thus providing incentives to develop such new knowledge 23 and helping parties to justify investments in research and development. They promote the diffusion of 24 this new knowledge via the detailed disclosure of the invention in the patent publication, and by 25 enabling a 'market for knowledge' via the trading of patents and the issuance of licenses (Arora et al. | Heritage | 2735 - 2735 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | 10 11 16.4.7 Sub-national innovation policies and industrial clusters 12 Research examining the impacts of sub-national policies on innovation and competitiveness is sporadic 13 – regional variations have been quantitatively assessed in US or China, or with case studies in these and 14 other countries. Research on wind energy in the United States, distributed PV balance of systems in 15 China, and renewable energy technologies in Italy have found that policies that incentivised local 16 demand were associated with inducing innovation, measured with patents (Fu et al. 2018; Gao and Rai 17 2019; Corsatea 2016). Different policies may have different impacts – for example, in the United States 18 state-level tax incentives and subsidies induced innovation within the state; but for renewable portfolio 19 standards policies in other states were associated with innovation, because of impact on demand, but 20 own-state policies were not (Fu et al. 2018). Research has also noted that the outcomes of policy and 21 regulation on innovation are spatially heterogenous, because of differences in local planning authorities 22 and capabilities (Song et al. 2019; Corsatea 2016). | Heritage | 2737 - 2737 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | 8 9 16.5.2 Objectives and roles of international technology transfer and cooperation efforts 10 International efforts involving technology transfer can have different objectives and roles. These 11 include access to knowledge and financial resources as well as promotion of new industries in both the 12 developed and recipient country (Huh and Kim 2018). Based on an econometric analysis of 13 international technology transfer factors and characteristics of Clean Development Mechanism (CDM) 14 projects, Gandenberger et al (2016) find that complexity and novelty of technologies explain whether 15 CDM project includes hardware technology transfer, and that factors like project size and absorptive 16 capacity of the host country do not seem to be drivers. Halleck Vega and Mandel (2018) argue that 17 'long-term economic relations', for instance being part of a customs union, affects technological 18 diffusion between countries for the case of wind energy, and indicate that this has resulted in low- 19 income countries being largely overlooked. | Heritage | 2740 - 2740 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | 7 Contributions of indigenous people (Díaz et al. 2019), heritage agriculture (Koohafkan and Altieri 8 2010) and peasants agroecological knowledge (Holt-Giménez 2002) to technological innovation offer 9 a wide array of options for management of land, soils, biodiversity and enhanced food security without 10 depending on modern, foreign agricultural technologies (Denevan 1995). In farming agriculture and 11 food systems, innovation and technology based on nature could help to reduce climate change impacts 12 (Griscom et al. 2017). Evidence suggests that there are benefits to integrating tradition with new 13 technologies in order to design new approaches to farming, and that these are greatest when they are 14 tailored to local circumstances (Nicholls and Altieri 2018). | Heritage | 2759 - 2759 |

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| Organisation | Document | Quotation Content | Codes | Page |
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| IPCC | IPCC_AR6_WGIII_Full_Report | 15 16 Accelerating the transition to sustainability will be enabled by explicit consideration being given 17 to the principles of justice, equality and fairness. Interventions to promote sustainability 18 transitions that account for local context (including unequal access to resources, capacity and 19 technology) in the development process are necessary but not sufficient in creating a just 20 transition (low evidence, high agreement). {17.4.6} 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 ACCEPTED VERSION SUBJECT TO FINAL EDITS Final Government Distribution Chapter 17 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 17-7 Total pages: 99 1 2 17.1 Introduction 3 This chapter focuses on the opportunities and challenges for "accelerating the transition in the context 4 of sustainable development." The chapter suggests that accelerating transitions in the context of 5 sustainable development requires more than concentrating on speed. Rather, it involves expediting the 6 pace of change (speed) while also removing the underlying drivers of vulnerability and high emissions 7 (quality and depth) and aligning the interests of different communities, regions, sectors, stakeholders 8 and cultures (scale and breadth). One key to enabling deep and broad transitions is integrating the views 9 of different government agencies, businesses and non-governmental organizations (NGOs) in transition 10 processes. Another critical driver of deep and broad transitions is engaging and empowering workers, 11 youth, women, the poor, minorities and marginalized stakeholders in just, equitable and inclusive 12 processes. The result of such processes will be the transformation of large-scale socioeconomic systems 13 to restore the health and well-being of the planet and the people on it. | Heritage | 2820 - 2821 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 20 17.1, the reference to "in the context of sustainable development" suggests that sustainable transitions 21 require more than speed, also necessitating removing the underlying drivers of vulnerability and high 22 emissions (quality and depth of transitions) while also aligning the interests of different individuals, 23 communities, sectors, stakeholders and cultures (scale and breadth of transitions). | Heritage | 2824 - 2824 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 28 29 An extensive literature has examined how the international climate agreements and architecture 30 influence collaboration across countries regarding climate and sustainable development to support a 31 transition (Bradley 2005). For example, international institutions offer opportunities for governments 32 and other actors to share new perspectives on integrated solutions (Cole 2015). For some observers, 33 however, decades of difficulties in crafting a comprehensive climate-change agreement and the 34 resulting fragmented climate-policy landscape have been inimical to the collaboration needed for a 35 transition (Chapter 1 and 13; Nasiritousi and Bäckstrand 2019; van Asselt 2014). Yet others see the 36 potential for more incremental cooperation across countries, even without a single, integrated forms of 37 climate governance (Keohane and Victor 2016). | Heritage | 2826 - 2826 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 54 ACCEPTED VERSION SUBJECT TO FINAL EDITS Final Government Distribution Chapter 17 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 17-15 Total pages: 99 1 Many of the above-mentioned beliefs and values that support climate actions have spread through 2 expanding interests in conservationist world views, indigenous cultures (see e.g., Lockhart 2011) and 3 branches of neuroscience and psychology that suggest different notions of the self (Hüther 2018; Lewis 4 2016; Seligman and Csikszentmihalyi 2014). These beliefs and values can also be spread through 5 meditation, yoga or other social practices that encourage lower carbon lifestyles (Woiwode and 6 Woiwode 2019). Another channel for spreading climate concerns is sustainability culture, which is 7 premised on connecting people and communities, and has also benefited from the internet and digital 8 technologies that support these connections (see e.g., Bradbury 2015; Scharmer 2018). The spread of 9 this culture, in turn, has led to the creation of social fields that allow changes to happen ( (see e.g., 10 Gillard et al. 2016) or has promoted low-carbon thinking and related behavioural changes (O'Brien 11 2018; Veciana and Ottmar 2018). Studies of social contagions may also offer insights into the 12 mechanisms that lead to the adoption of new values and related climate actions (see e.g., Iacopini et al. | Heritage | 2828 - 2829 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 23 24 17.2.5 Conclusions 25 This section has surveyed several explanations for interventions that can give rise to transitions. The 26 review suggests that there are several differences between these various perspectives. Whether 27 individuals, organisations, markets or sociotechnical systems drive or undermine transitions is a key 28 distinction. These differences have implications for the evidence these claims draw on in support of 29 their arguments. For instance, some of the explanations tend to employ qualitative evidence to explain 30 changes in attitudes at the individual or community levels as paving the way for broader changes to 31 cultures and belief systems. Others assess how institutional arrangements can be reformed in order to 32 align climate with the sustainable development agenda to enable a transition. | Heritage | 2830 - 2830 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 4 5 Okereke et al. (2019) offer important generic conclusions on green industrialisation and the transition 6 based on a study of socio-technical transition in Ethiopia. The importance of drivers for changes in 7 terms of clear policy goals and government support for green growth and climate policies, as well as 8 support from a strong culture of innovation, is emphasized. The study also identifies key barriers in 9 relation to stakeholder interactions, the availability of resources and the ongoing tensions between 10 ambitions for high economic growth and climate change. Green innovation in industry critically 11 depends on regulations. Gramkow and Anger-Kraavi (2018) have assessed the role of fiscal policies in 12 greening Brazilian industry based on an econometric analysis of 24 manufacturing sectors. They 13 conclude that instruments like low-cost finance for innovation and support to sustainable practices 14 effectively promote green innovation. | Heritage | 2855 - 2855 |

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| Organisation | Document | Quotation Content | Codes | Page |
|---|---|---|---|---|
| IPCC | IPCC_AR6_WGIII_Full_Report | 43 ACCEPTED VERSION SUBJECT TO FINAL EDITS Final Government Distribution Chapter 17 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 17-51 Total pages: 99 1 2 3 Figure 17.1 Trade-offs and synergies between sectoral mitigation options and the SDGs 4 5 6 Most of the energy sector options are assessed as having synergies with several SDGs, but there could 7 be mixed synergies and trade-offs between SDG 2 'zero hunger' for wind and solar energy, and for 8 hydropower due to land-use conflicts and fishery damage. Offshore wind could also have both synergies 9 and trade-offs with SDG 14 'life below water' dependent on scale and implementation site, and it is 10 emphasized that land-use should be coordinated with biodiversity concerns. Both wind and solar energy ACCEPTED VERSION SUBJECT TO FINAL EDITS Final Government Distribution Chapter 17 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 17-52 Total pages: 99 1 are assessed as having trade-offs with SDG 12 'responsible production and consumption' due to 2 significant material consumption and disposal needs. | Heritage | 2864 - 2866 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 49 50 Indeed, individual actions are necessary but insufficient to deliver transformative mitigation, and it is 51 suggested that this be coupled with collective actions to accelerate the transition to sustainable 52 development (Dugast et al. 2019). Actors with conflicting interests will compete to frame mitigation 53 technologies that either "build or erode" the legitimacy of the technology, contested framing sites that 54 can occur between incumbent and emerging actors or between actors in new but competing spaces ACCEPTED VERSION SUBJECT TO FINAL EDITS Final Government Distribution Chapter 17 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 17-56 Total pages: 99 1 (Rosenbloom et al. 2016). How narratives are built around desired development pathways and specific 2 emerging technologies, as well as how local values are integrated into visions of the future, have 3 relevance for how these experiments are managed and enabled to expand (Horcea-Milcu et al. 2020; 4 Lam et al. 2020). | Heritage | 2869 - 2870 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 18 19 It was Theory-U (Scharmer 2018, building on the work of scholars like Schein, Lewin or Senge) that 20 inspired a so-called "massive open online course" (MOOC) jointly initiated by the Bhutan Happiness 21 Institute and German Technical Assistance (GIZ) in 2015, since when it has been developed further and 22 adapted to transform business, society and self as one example of how social movements can go together 23 with science and education. It brings together people from different professions, cultures and continents 24 in shared discussions and practices of sustainability. It also included marginalised communities and is 25 shifting towards more sustainable lifestyles in all sectors (Nikas et al. 2020), including climate action. | Heritage | 2870 - 2870 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 26 27 Moreover, approaches like the "Art of Hosting" (Sandfort and Quick 2015) and qualitative research 28 methods like storytelling and first-person research, as well as second-person inquiries, for example 29 (Scharmer, C, Kaufer 2015; Trullen and Torbert 2004; Varela 1999), have been employed to bridge 30 differences in cultures and sciences, as well as to forge connections between those working on climate 31 change and sustainable development. Likewise, experiential tools, simulations and role-playing games 32 have been shown to increase knowledge of the causes and consequences of climate change, the sense 33 of urgency around action and the desire to pursue further learning (Ahamer 2013; Eisenack and Reckien 34 2013; Hallinger et al. 2020; Rooney-Varga et al. 2020). | Heritage | 2870 - 2870 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 49 50 A related line of inquiry involves education for sustainable development (ESD). This builds on the 51 UNESCO programme, 'ESD for 2030', and involves core values like peace culture, valuing cultural 52 diversity and living global citizenship. One of the core insights from research on ESC is lifelong 53 education continuing outside the classroom, a lifelong learning process that involves sustained actions 54 by all ages and social segments (see e.g., Hume and Barry 2015) and achieving collaboration (Munger 55 and Riemer 2012). Some authors have pointed to good levels of communication either directly or ACCEPTED VERSION SUBJECT TO FINAL EDITS Final Government Distribution Chapter 17 IPCC AR6 WGIII Do Not Cite, Quote or Distribute 17-57 Total pages: 99 1 through the internet as the key to facilitating this learning (Sandfort and Quick 2015). Others have noted 2 that transformative learning – that is, deepening the learning process – is critical because it helps to 3 induce both shared awareness and collective actions (see e.g., Brundiers et al. 2010; Singleton 2015; 4 Wamsler and Brink 2018). | Heritage | 2870 - 2871 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 33 However, government agencies with climate and other remits do not always work well together: the 34 absence of coordination and consensus building mechanisms can further deepen inter-agency conflicts 35 that stall a transition. These challenges appear not only within but also between levels of decision- 36 making. Studies of developing megacities, for instance, have found the lack of mechanisms promoting 37 vertical cross-level integration to be a sizable constraint on decarbonisation (Canitez 2019). Differences 38 in perspectives across non-state actors can similarly frustrate transitions in areas such as green buildings 39 (Song et al. 2020). | Heritage | 2873 - 2873 |
| IPCC | IPCC_AR6_WGIII_Full_Report | 14 Furthermore, this is how existing institutions interact with ideas that often strengthen lock-ins. To 15 illustrate, studies have shown that the status-quo orientations of leaders (including decision-makers' 16 disciplinary backgrounds, world views and perceptions of risk) (Willis 2018), as well as the 17 organizational culture and management paradigms within which they operate, affect the speed and 18 ambitions of climate policies (Rickards et al., 2014). | Heritage | 2874 - 2874 |

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| IPCC | IPCC_AR6_WGIII_Full_ Report | 42  43 Intersectional theory can shine a light on the hidden costs of resource extraction, as well as renewable   44 energy development (see, for instance, (Chatalova and Balmann 2017), which go beyond environmental   45 or health risks to include the socio-cultural impacts on both communities adjacent to these sites and   46 those who work in them (Daum 2018). Indeed, development decisions often do not properly integrate   47 the burdens and risks placed on marginalized groups, like indigenous peoples, while risk assessments   48 tend to reinforce existing power imbalances by failing to differentiate between how benefits and risks   49 might impact on certain groups (Healy et al. 2019; Kojola 2019). In some cases, such as the deployment   50 of small-scale solar power in Tanzania by a non-profit organization, an explicit gender lens on the   51 impacts of energy poverty revealed the significant socio-economic benefits of improving access to   52 renewable energy (Gray et al. 2019). | Heritage | 2875 - 2875 |
| IPCC | IPCC_AR6_WGIII_Full_ Report | 20  21  22 17.5 Conclusions  23 This chapter has been concerned to assess the opportunities and challenges for acceleration in the   24 context of sustainable development. As such, many of the claims reviewed involve not only increasing   25 the speed of the transition but also ensuring that it is just, equitable and delivers a wider range of   26 environmental and social benefits. A sustainability transition requires removing the underlying drivers   27 of vulnerability and high emissions (quality and depth) while aligning the interests of different   28 communities, regions, sectors, stakeholders and cultures (scale and breadth). | Heritage | 2877 - 2877 |