**Background S1**

**Cocoa and chocolate: a brief background**

Cocoa (*Theobroma cacao*) only grows in narrow belt 10 degrees either side of the Equator, so cultivation is restricted to a small number of countries. The commodity is mainly produced in Africa (73% of global total), with Ivory Coast leading the charts (40%) followed by Ghana (20%), while Brazil ranks at 6th pace coming after Indonesia, Ecuador, Cameron, and Nigeria (ICCO 2017).

Ghana is a large cocoa producer, but there has been a rapid transition from traditional shaded cocoa cultivation (under primary or secondary forests) to increasingly open cocoa cultivation over the last years (F Ruf, Deheuvels, & Sarpong, 2006), (Hainmueller, Hiscox, & Tampe, 2011), (Ruf, Schroth & Doffangui 2015). This has been driven mainly by higher short-term profit and increasing competition for land, among other issues. Recent estimates suggest that shaded cocoa only accounts for less than 30 per cent in Ghana, and it is estimated that this transition to open cultivation represents a loss of about 50 per cent of the carbon stocks.

Brazil was once among the top producers of cocoa in the globe, but in the1980s there was an outbreak of witches’ broom disease in the cocoa agricultural system (Alger & Caldas 1994). To contain the spread of the disease, entire  cocoa plantations were burned to eradicate the fungus. Brazil never recovered its plantations, but there are some efforts to re-structure the country to grow the commodity in large areas under agroforestry systems (Caldas & Perz 2013) (Müller 2012). Nonetheless, the lack of technical assistance to farmers still is a major constraint so a large amount of production is being carried in open sun areas (Caldas & Perz 2013).

The Netherlands is the largest importer of cocoa globally, mainly from West Africa (90%). In Europe, this country holds a market share of 37%, followed by Germany and Belgium, with 19% and 15% respectively (Ministry of Foreign Affairs of The Netherlands 2016). The main chocolate consuming regions are: the European Union (36%), North America (24%), and Asia and Oceania (16%) (ICCO 2014)

Estimates suggest that over 80% of cocoa comes from seven to eight million small family-managed cocoa farms around the globe (FAO 2014b). These primary stakeholders have little capital and low investment capacity for technical innovation, resulting in low yields and high vulnerability to cocoa price volatility, pests and diseases (Laderach *et al.* 2013; Afoakwa 2014) Most farmers struggle with poverty, which is rooted in low cocoa prices, a lack of farmer associations to self-organize, tenure uncertainties, and a lack of infrastructure and access to markets. The sector constantly battles child labour, and there is an increasing disinterest in the youth to continue in their parents footsteps to become cocoa farmers (Fountain & Hütz-Adams 2015).

Despite all the challenges, cocoa is still a very important cash crop for the millions of farmers, and national economies of several countries in West Africa. For example, in 2011, cocoa was the most important agricultural export by value for Ivory Coast, Ghana, Nigeria, Cameroon and Sierra Leone (FAO 2014a). In Ghana, cocoa accounted for over 67% of household income in most of the 700 thousand cocoa farmer households, while contributing to 8.2% of the country’s GDP and 30% of total export earnings in 2010 (Asante-Poku & Angelucci 2013).

Notwithstanding the benefits that cocoa brings, it has been directly linked to deforestation and forest degradation in production areas throughout the world (Gockowski & Sonwa 2011). Research suggests that over the last 50 years, cocoa cultivation has contributed to the disappearance of 14–15 million ha of tropical forests globally (around 2 million in Cote d’Ivoire, 1.5 million in Ghana and over 1 million ha in Indonesia) (Clough *et al.* 2009). To attend to the growing international market, especially in Asia (Nierhoff 2014), production continues to expand, further increasing pressure on forest areas. During the period of 2000-2013, cocoa was the fastest expanding export-oriented crop across Sub-Saharan Africa, with an average of 132 000 ha of new production area per year. According to Ordway et al (2017), Ivory Coast ranks as one of the countries with the highest risk for forest conversion due to the projected expansion of cocoa for export.

Despite the fact that cocoa production has a lower contribution to deforestation when compared to other commodities such as beef, soy and palm oil (H enders *et al.* 2015), it is not less important to address the impacts of cocoa on forest conversion given that forest loss has been leading to local and regional climatic changes (Laderach *et al.* 2013). These changes will likely impact not only cocoa production, but also the livelihoods of millions of people living in the cocoa belt. Studies have been suggesting that climate change will increase droughts and affect the suitability for cocoa production in West Africa, impacting cocoa supply as well as farmer’s livelihoods and the national economies (Schroth *et al.* 2016; Coulibaly *et al.* 2017).

**From cocoa to chocolate**

Cocoa is the key ingredient of chocolate. European Union regulations stipulate that chocolate products must contain no less than 35% total dry cocoa solids (Council Directive 2000/36/EC). The other basic ingredients mixed with cocoa butter and chocolate liquor are sugar, lecithin, vanilla, milk powder, and products such as nuts to give flavour. All of these ingredients have their own supply chains with sustainability challenges (Eggleston 2010; Faye & Konuspayeva 2012).

Several other sectors still need to interact before chocolate – the final product – can be produced. It begins with the agricultural inputs industry (e.g. seedlings, fertilizers) before even reaching the farmers, who in turn sell their products to local buyers (traders).  Part of the cocoa is then processed (roasted and ground into semi-finished products – butter, powder, chocolate liquor) and transported (mostly to Europe) by ship. The outputs are sold to chocolate manufacturers that blend ingredients and finalize the product, which is packed in aluminium foil and paper before being transported to retailers. After consuming the product the packaging is partly recycled and partly disposed of in landfill or in incineration plants (Afoakwa 2014).

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