SUPPLEMENTARY MATERIAL E

Current techniques and future techniques proposed by experts as necessary to meet the research gaps

Current Techniques

- Conservation rice farming method.
- Using ducks to reduce labour in weeding
- Implementation of Complex Rice Systems at landscape scale
- Quantitative approach on impact evaluation and policy evaluation
- Spatiotemporal analysis of land suitability
- Spatial analysis; Land cover changes and cropland expansions, crop type mapping
- Analyse transition from low-input (dryland) to high-input (wetland) rice systems
- Mapping and characterizing rice growing environments especially lowland / inland valleys
  Developing Early warning systems and/or decision-support tools
- Characterizing where risks and opportunities are regarding climate change impacts on rice production
- Advance high throughput phenotyping platforms and field-based plant phenotyping tools can potentially answer how rice response changes under a complex environment
- Including expert opinion on rice economics and trade
- Awareness and training.
- Methods for GXE and multiple environments GWAS.
- Regarding the gene discovery, we use several related techniques to identify the actors from smRNAs to proteins
- Behavioural/experimental economics
- Policy formulation and program evaluation
- Better cost-benefit analysis of maintenance work
- Collaboration with private agri-businesses.
- Rent system for storage room for paddy and white rice
- Integration of research in the national politics
- By-product usage in Biogas plants to digest cellulose and hemicellulose in a containerized solution.
- Co-production of knowledge
- Proper calibration of modelling for forecasting.
- Training farmers on how to use technology
- Develop soil amendments which have electron receptors
- Development of rice-based cropping system to diversify rice enterprise
- Identification for mechanisms rice varieties use to cope with the effect of climate change for breeding climate-smart varieties
- Economic (fair sustainable business models and supply chains)
- Ethnobotany
- Understand local farming systems

- Explain motivations of small farmers to government / academia
- Discover links between traditional crops and survival
- Evolution of weed flora and herbicide resistant specie
- Experimental simulation using crop modelling
- Land suitability analyses using ecological niche modelling
- Development, validation and scaling of climate-smart agriculture technologies and climate information services
- Capacity building of stakeholders at national and local levels.
- Field phenotyping of rice, novel genes discovery to improve rice resilience to adverse conditions.
- Pest/disease monitoring based on mobile phone app.
- Development of abiotic stress tolerant varieties using genomic assisted tools
- Extension activities for transfer of technology. Such as farmers training, exposure, visits, surveys, field demonstrations etc.
- Further refinement of the Sustainable Rice Platform (SRP) Standard and its assurance scheme.
- Stakeholder engagement along the value chain to ensure adoption of climate smart rice varieties
- Good production and post-harvest techniques
- Social surveys to answer questions such as “How do new varieties respond to the environmental conditions in farmers' fields to better understand why farmers do or do not continue growing a new variety.”
- Improving resource use efficiencies
- Influencing policy decisions for betterment of rice production
- Rice-fish system
- Nitrogen application techniques
- Innovative climate finance and business models
- Investment in agricultural research and development
- Biotechnological methods and tools
- Machine learning, big data applications including GIS and satellite data
- Digital methods and tools
- Agrifood value chains
- Testing and dissemination of modern technologies at local level
- Knowledge in analysing and quantifying the GHG emissions produced.
- Controlled environment farming such as is being embraced by the horticulture industry
- Knowledge/expertise on weed and parasitic weed ecology and management.
- Knowledge/expertise on developing more water-use efficient and nutrient-efficient cropping systems (mainly in Africa).
- Near-real-time crop simulations and monitoring
- Yield simulations and estimations
- Making small and family rice farming climate and technology smart: collective impact approach
- Market sorting experiments to reveal consumer preferred grain quality traits across Africa

- Screening of existing germplasm for Glycaemic index, grain Protein Fe, Zn and phytate
- Support the piloting and scaling of climate resilient, environmentally friendly and gender responsive technologies in Africa through different technology delivery infrastructures
- Multi-stakeholder Innovation platforms, Consortium of rice seeds enterprises and millers, Integrated Youths in Agribusiness hubs and Individual private companies.
- Multidisciplinary approach
- Modelling and participative research
- Multi-level perspective analysis
- Game theory applied in land-use planning
- Understanding processes of technological change (often known as 'innovation')
- Land levelling techniques
- System design
- Participatory research among the key players in rice value chain
- Policy analysis methods and impact assessment tools
- Polycultures and complex rice systems
- Permaculture
- Water harvesting
- Sustainable local seed systems
- Practical demonstration of prospects in rice agronomy and processing
- research on how trait variation is partitioned across genetic groups could enable greater understanding of which combinations are beneficial in future conditions
- Policy research
- Engineering for designing and manufacturing low-cost machines for direct seeding
- Capacity building
- Competitive funding opportunities for rice research and education of the next-generation rice farmers and professionals
- Investment in digitalization of the rice value chain (low-cost digitalization and open-source knowledge)"
- Alternate wetting and drying
- Slow-release N fertilizer
- Rice modelling
- Rice-vegetable systems and farming systems.
- Scaling up new rice technologies - example of Smart-Valleys technology
- Demand-driven technologies, rather than the most advanced or one-size-fit-all ones, are critical for the rapid adoption
- Stakeholder engagement methods to study stakeholder perceptions and develop robust solutions
- Input optimization analysis
- Appropriate mechanization

- Training in the fabrication of prototype equipment for land and post-harvest operations
- Promote collaboration between stakeholders in production, market, policy maker, manager, scientist
- Use of weed science to manage weeds with different control methods, like crop rotation, physical methods, and chemical methods.
- Value chain mapping; analysing cropping systems rather than individual crops; understanding limitations of top-down technology transfer due to demographic, infrastructural, socioeconomic, and agroclimatic circumstances
- Water accounting. This will help provide a spatially explicit account of water available, how much is used for specific sector and how much remains for further allocation.
- High-level policy dialogues

Future Techniques

- Better data on areas cultivated with rice (distinguish between dryland and wetland)
- Crop simulation models of rice yields under different management conditions
- Couple data on historic and projected climate change with hydrological models to analyse water consumption
- Capturing the heterogeneity (in biophysical, environmental, social, economic, policy domains) in the current research in the key to be better prepared for the projected changes "
- Rice yield improvement on rice conservation farming systems
- Potential exchanges between duck and rice farmers
- Development of method to landscape approaches for those sustainable rice farming"
- small farmer friendly climate smart technology development
- fast-tracking urban demand and supply of quality rice
- small farmer friendly policies development
- regional cooperation for equitable use of water resources
- Adequate engagement of farmers, processors, policy makers and users in the research agenda
- More socio-economic research in rice systems to recommend optimum investments in rice businesses
- Machine learning can play a pivotal role
- Work more with the private sector
- Build the capacity of the next generation of agricultural scientists, extension workers, policymakers, and leaders in the food systems
- Engage with governments on policy and multi-sectoral partnerships on achieving SDGs
- Artificial intelligence
- Connectivity in rural areas

- Low-cost mechanization and digitalization throughout the rice value chain
- Water-saving and smarter use of water for irrigation (policies, technologies, capacity building)
- Cooperation: Funding opportunities shall prioritize access to global or regional partnerships
- Public-private partnerships
- Breeding and science aspect, we need to study Africa such as weather, soil, culture.
- Circular agronomy
- Farming as business
- Improved resource use efficiencies
- Precision Agriculture
- Collaboration and training of farmers, experts and decision makers will be key.
- Collaboration between scientists coming from different areas and sectors to connect different parts of the whole system together and find out the real driving factors.
- Cross-system research, i.e. rice-shrimp, rice-upland crop, etc.
- Develop green rice which can produce less CH4 emission and higher productivity
- Develop functional soil amendments and fertilizers which can suppress methane flux in rice paddy
- Developing sustainable intensification methods for smallholder farmers in Africa (e.g. , including alternate wetting and drying combined with adapted varieties. integrated pest/weed management options under changing climates, purposeful integration of trees in rice production systems, increasing crop diversity).
- Development of floating and perennial rice that sustainability harvested
- Digital agriculture
- Efficient suitable rice variety breeding for each ecology and local conditions.
- Detailed mapping of suitable locally rice production areas according to each main rice agroecology (irrigated lowland, rainfed lowland, mangrove, highland)."
- Engagement with stakeholders and policy makers
- Translating available research evidence into actionable policy instrument to make changes"
- Focus on the economical parts of scaling.
- Systemic approach
- Mapping
- Multidisciplinary studies
- Herbicides residues effect, the importance of micro nutrients for rice and post-technology will be needed to fill the research gaps for a sustainable rice future.
- high throughput phenotyping, genetic composition modification from discovery of novel genes to rice resilience to adverse climatic conditions. Socio-economic research on impacts on rice farmers on less rice production.
- High vitamin, Omega 3 rice breeding

- 15N isotope technical
- 13 Carbon technical
- Transdisciplinary research approach (research has a very practical, actionable orientation, engaged with communities and their knowledge and practices and situations).
- Most methods and tools are available, but underutilized.
- Identification of climate-smart varieties on regional basis
- Identification of compatible crops in rice-based cropping system "
- Improved varieties; disease resistant varieties, manufacture of modified equipment for cultivation, processing and marketing
- Going back to the basics, without critical core expertise in many areas of science such as soil science, crop nutrition, crop health, agronomy or crop physiology. Without these basics, it is not possible to tackle bigger challenges in a multi- and transdisciplinary manner.
- Interdisciplinary (not just beta-gamma, but alpha-beta-gamma),
- Multi-actor research approaches
- Increased and sustainable investment in agricultural R&D from governments
- Public-private partnership
- Finding an equilibrium between fundamental, applied research and development initiative
- Innovative thinking by looking at solutions that have been successful in other sectors (energy, health, transportation, etc.) and adapting the approach to agriculture.
- Large scale behaviour change is necessary which will also require adapting successful approaches to behaviour change from other sectors, such as health and education.
- Rapid and inclusive technology development and iterative testing and design processes with users that allow for quick research and development cycles and value failures as learning opportunities.
- It will be crucial to ensure stable, long-term funding for basic rice science research
- "It will be need based research which will vary as per regional, local needs
- Researchers can focus their research on more applied aspect towards product development and delivery and creation of more impactful scientific manuscripts whose recommendation will be more adaptable, repeatable and stainable across the globe."
- Long term vision in planning
- Multifunctional agriculture
- Agro-ecological rice systems
- Market research for sustainably cultivated rice and of rice free of residues.
- Nature-based solutions
- Less dependence on business interest of multinationals
- Reducing the fragility of smallholder farmer systems

- Most of the sustainable rice work is targeted towards plot level, seasons and individual levels. The interaction of various production system factors as well as value chain segments is poorly understood.
- Sustainability needs to be assessed at a system-level and at scale.
- Multi-disciplinary collaborative research
- Policy support and implementation that support domestic rice production and sector development in SSA countries.
- Strategy to conserve agro diversity in situ (on farms) not only in germplasm banks
- Research needs to be translated into actual solutions. Most of research and strategies on rice/agriculture production are available, but the implementation/operation is very limited. Remote sensing is a good example. While many research groups have been focusing on the topics for years, barely any solutions are in use today.
- Research on policy aspect and technologies
- Research on water-rice production and flow dynamics of the Mekong River
- Technologies in rice root biology and growth in soilless media
- Scientific and Indigenous knowledge integration
- Space applications
- Advance remote sensing applications
- Automated crop monitoring
- Strong collaboration with the physical and social science groups.
- Strong policies that focus on regional programs, rather than national policies in Africa.
- Sustainable and inclusive scaling mechanisms to ensure the adoption of technologies.
- Crop insurance
- Sustainable financing mechanisms
- Technology-based agronomy to be more resource and input efficient.
- Generate long term data to fill models to evaluate possible production trends, pros and cons.
- the research objective is based on the specific requires of each local condition and shortening the procedure and period of field testing.
- Understanding incentives. Farmers need more incentives to a) choose farming as a career, b) implement environmentally-friendly management practices, and c) adopt new varieties. This understanding of incentives should feedback to those developing new technologies (breeders, agronomists).
- "Upland rice production, improve variety to reduce water use and improve yield.
- Expertise knowledge and environmental experience need to work together.
- land use plan should be implemented accordingly and allocation of water resources should be managed to avoid water loss
- Improve rainwater harvesting and utilization for Agricultural production
- Improve irrigation infrastructure and water storage facility

- Reduction of production cost in agriculture production and improve commercial rice production
- Use of biotechnological methods
- Digital methods and tools
- Viewing rice not just as a commodity but part of a cropping system and ecosystem.
- Multi-stakeholder engagement-- involving various stakeholders to shape research agendas.
- Water management that will allow diversification in the rice-based system.
- Biodiversity management that will improve ecosystem services in rice-based systems.
- How can technology be adopted by smallholder farmers in more efficient way."
- Integrated water management might still be valuable