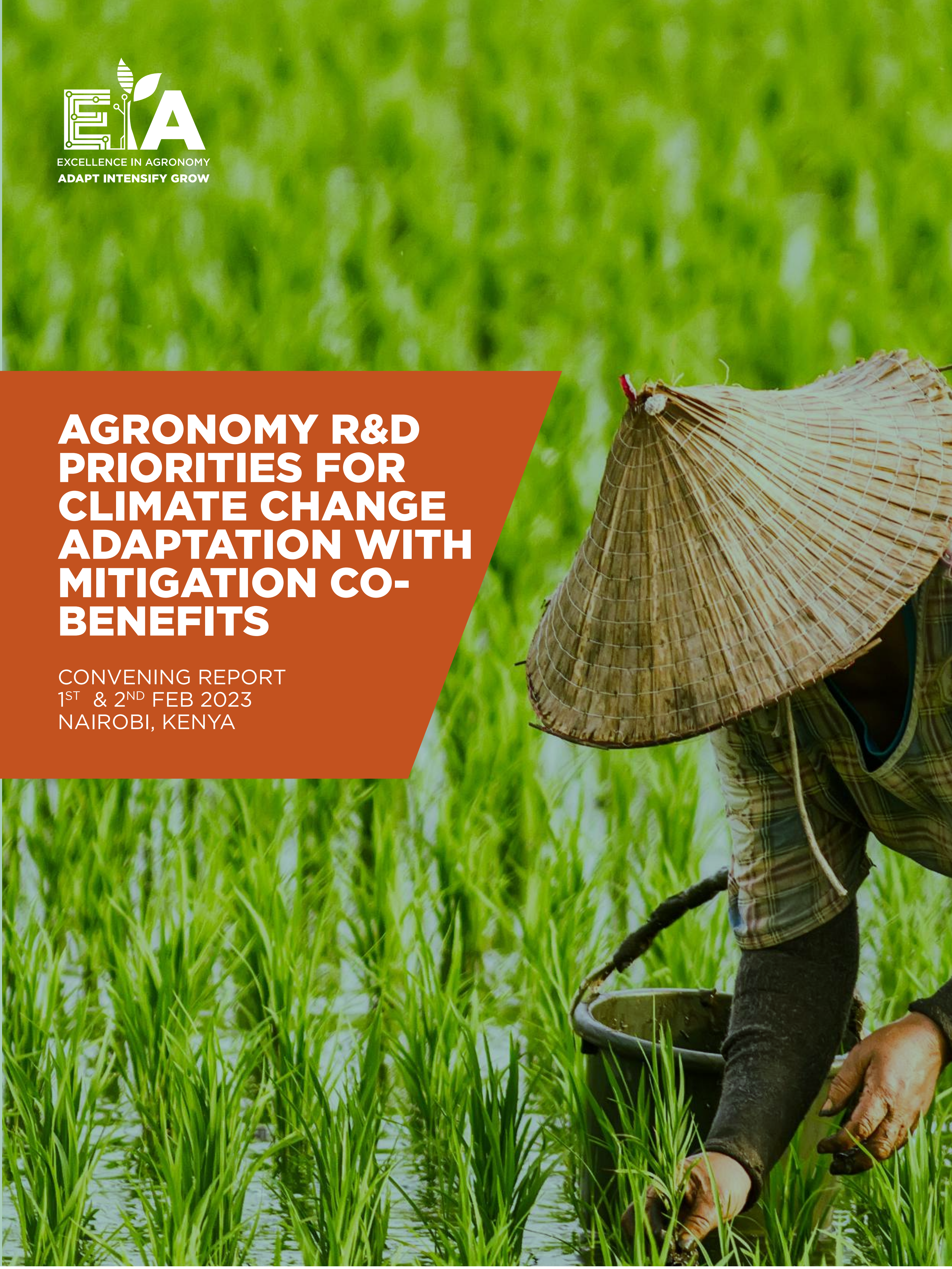


EXCELLENCE IN AGRONOMY
ADAPT INTENSIFY GROW

AGRONOMY R&D PRIORITIES FOR CLIMATE CHANGE ADAPTATION WITH MITIGATION CO-BENEFITS

CONVENING REPORT
1ST & 2ND FEB 2023
NAIROBI, KENYA

CGIAR

BILL & MELINDA GATES foundation

> Agronomy provides solutions for smallholder farming systems to adapt to climate change, but there are no one-size-fits-all solutions.

EXCELLENCE IN AGRONOMY
ADAPT INTENSIFY GROW

CONTENTS

1. KEY MESSAGES FROM THE CONVENING 4
2. BACKGROUND TO THE CONVENING 6
3. OBJECTIVES OF THE TWO-DAY CONVENE WORKSHOP 7
4. CHALLENGING EIA'S CLIMATE LOGIC ON IDENTIFYING AND PRIORITIZING SOLUTIONS 7
5. IDENTIFYING ENABLERS AND PARTNERSHIPS TO SCALE CLIMATE ADAPTATION SOLUTIONS 9
6. MEASURING AND MONITORING CLIMATE ADAPTATION 11
7. STRENGTHENING EIA'S FUTURE RESEARCH AGENDA ON CLIMATE ADAPTATION 12

ANNEX 1 THE VERSION OF THE STRATEGIC PAPER CIRCULATED PRIOR TO THE CONVENING 16

ANNEX 2 CONVENING AGENDA 36

ANNEX 3 CONVENING SLIDE DECK 39

ANNEX 4 THE CAPTAIN (THE CLIMATE ADAPTATION PRIORITIZATION TOOL) 40

ANNEX 5 SUMMARY OF INFORMATION COLLECTED IN THE BREAKOUT SESSIONS 42

1. KEY MESSAGES FROM THE CONVENING

Smallholder farmers and their cropping systems are already exposed and vulnerable to climate variability and extremes. The risks faced by farmers of different capacities are determined by the exposure to climate hazards, their frequency, and the wider socio-economic environment. Agronomy provides solutions for smallholder farming systems to adapt to climate change, but there are no one-size-fits-all solutions. To adapt effectively, adaptive measures need to be specific to local contexts, consider differences in risk perception, and be adaptive to farmers' ability and capability to adapt.

The Bill & Melinda Gates Foundation with The CGIAR Excellence in Agronomy (EiA) Initiative co-hosted a two-day convening event in Nairobi to identify climate change-related agronomy research priorities and partnership opportunities for the new initiative. Prior to the convening, EiA shared its strategy paper "Agronomic adaptive strategies to strengthen smallholder farmers' resilience to climate change" with the participants (see Annex 1). The aim was to further EiA's research for development agenda in support of smallholder farmers in adapting to climate change by developing location-specific solutions that consider the social, economic, and technical contexts.

The key messages assembled during the convening are housed under its four main topics:

A. Prioritizing agronomic interventions
B. Enablers and partnerships to reach scale
C. Monitoring and measuring climate adaptation progress
D. Priority research areas

A. PRIORITIZING AGRONOMIC INTERVENTIONS TO SUPPORT SMALLHOLDER CLIMATE ADAPTATION

Insights from the session:

- Climate change creates various hazards that manifest with varying degrees of intensity across different regions.
- While EiA is currently organizing its agronomic responses against 5 such hazards (drought, flood, climate variability, growing season reduction and heat stress) these categories are rather generic and may require a more specific description and interpretation at the regional level.
- The prioritization framework fills an important knowledge gap by formalizing priority setting through participatory processes and by providing a collaboration platform for learning and consensus building towards joint action.
- The framework increases decision-making transparency and 'makes the case' for targeted agronomic solutions addressing the climate crisis.
- Expert facilitation and inclusion will be essential to prioritization workshops' success. Group composition will have a disproportionate influence on the outcomes of prioritization workshops; participants must be carefully selected, and more stakeholders consulted thereafter.
- Ensure that the questions in the prioritization framework are as clearly posed as possible; the tool was well-received but 'tightening' on some topics and indicators is required.
- Ensure that data related to climate hazards and effects on cropping systems is populated, to create an objective starting point for expert solicitation.

Action points for EiA:

- Improve the CAPTain tool by incorporating the convening participants' feedback – May 2023.
- Add default data layers to facilitate rollout and standardization – June 2023.
- There is no global playbook to address climate adaptation. EiA should identify common agro-ecological zones, climate hazards and crop production systems when rolling out its prioritization framework for climate adaptation – May 2023.
- Finalize EiA's strategy paper- June 2023.
- Develop an opinion piece in Nature Food and feed this into Cop28 by September 2023.
- Roll out the prioritization framework for agronomic interventions to support climate adaptation through the regions using the CAPTain tool and feed the results into the second business cycle: June – December 2023.

B. ENABLERS AND PARTNERSHIPS TO SCALE CLIMATE ADAPTATION SOLUTIONS:

Insights from the session

- Enablers are as important as practices and technologies: it is important to strengthen partnerships that support influencing key enabling levers to enhance the impact of climate adaptative agronomic practices. These enablers include influencing policy, markets, knowledge finance etc.
- Bundling of agronomic solutions with other socio-technological innovations, adapted to the broader enabling environment, is key to enhance smallholder adaptive capacity to climate change.
- Partnerships to reach scale require an understanding of their climate related risk perception, alignment of incentives and clear roles and responsibilities. Furthermore, partnerships can change across the scaling process depending on altering geographies, new climatic hazards, and the risk perception of venturing in new markets.
- Making the enabling environment more climate adaptive and conducive for scaling climate adaptation solutions are not core to EiA; engagement with other CGIAR Initiatives is critical to achieve impact.
- There needs to be a feedback mechanism established to evaluate partnerships across the scaling process.
- Advocacy is needed to bring socio-technological innovation bundles in agronomy closer to the climate adaptation discussions as there is often a lack of understanding regarding the potential actions that can be taken.

Action points for EiA

- Use cases to apply adaptive management to partnerships and bundling of innovations to enhance climate adaptiveness of services provided – this is continuous throughout EiA's program.
- EiA to work with the Climate Platform to identify strategic partnerships to further advance the Initiative's agenda on climate adaptation whilst enhancing its visibility globally – December 2023.
- Develop with the Climate platform, a global narrative highlighting the pivotal role of agronomy in climate adaptation – October 2023.
- Review methodologies to assess climate related risks and the related perception of partners are crucial to support scaling of EiA's solutions – March 2024.
- EiA needs to identify how climate related risks influence the enabling environment and potentially hamper agronomic solutions from going to scale – framework developed in 2024.

C. MONITORING AND MEASURING CLIMATE ADAPTATION:

Insights from the session

- Many frameworks are available. However data requirements make them unsuitable for EiA.
- There is a need for streamlining approaches to evaluate technical agronomic practices and their impacts on climate adaptation building upon earlier efforts (e.g.; ERA).
- Tracking adaptation for agronomy represents an important new area of research and while many of the technical ingredients are available, practical frameworks will need to be developed and validated to serve the agronomic community going forward.
- Tracking adaptation requires linking bio-physical to behavioral change, socio-economic frameworks and cover various spatial and temporal scales. EiA's adaptation framework needs to also relate to sustainability, given the program's scope.
- Long-term experiments are needed to generate the necessary data on potential for climate adaptation; to be combined with modelling tools.

Action points for EiA

- Develop a consolidated workflow to assess the climate adaptiveness for use cases and their MVP – Oct 2023.
- Develop a monitoring framework and practical tools to monitor the impact of EiA's practices along the adaptiveness spectrum including its interaction with the environment – March 2024.

D. STRENGTHENING EIA'S FUTURE RESEARCH AGENDA ON CLIMATE ADAPTATION

Insights from the session

- Research is needed to unpack how climate change affects sustainable intensification pathways, how technologies and technology bundles respond within systems experiencing climate stress. Additionally, it is crucial to examine the barriers faced by smallholders in adopting adaptation measures. Moreover, exploring the trade-offs and synergies between adaptation and sustainable intensification is essential.

- A priority research issue relates to changes in the agronomy R&D systems that are necessary to understand and address climate adaptation needs. We need to evaluate climate-related impact on yield gaps and use data from existing long-term experiments to evaluate adaptation potential of key agronomic practices (e.g., analyze system performance in stressful or extreme years). Likewise, the agronomy community should design experiments to evaluate agronomic adaptation interventions with a focus on future climate conditions, making use of climate analogues and homologues approaches.

- The agronomy community must maximize the use of climate predictions. This entails assessing their effectiveness, enhancing their accuracy by calibrating and rectifying biases, adjusting them to the suitable spatio-temporal resolution for making agronomy-related decisions, and integrating them into agronomic advisory services. The agronomy community should review the experience of the Food Security and Famine early warning community as a starting point.

- Disruptive innovation is possible especially with regard to environmental and farming system monitoring (leveraging earth observation), data ownership, and (positively and responsibly) influencing farmer behavior. Several disruptive technologies are already available that EiA can leverage into agronomy R&D processes in various use cases.

Action points for EiA

- Develop a targeted R&D agenda for the second business cycle to enhance EiA's climate adaptation agenda – December 2023.

- Develop strategic partnerships with key research institutes and renowned climate science experts – continuously through the EiA program.

2. BACKGROUND TO THE CONVENING

Smallholder farmers and their cropping systems are already exposed and vulnerable to climate variability and extremes. Climate change is shortening growing seasons, creating more erratic rainfall patterns, increasing the probability of damaging temperatures, and, in general, eroding the climate system predictability that farmers rely on to make sound management decisions based on experience. Risks among farmers of different capacities are mediated by exposure to climate hazards and their frequency as well as the wider socio-economic enabling environment. Hence, adaptive measures must be specific to local contexts and adaptive to differences in risk perception, ability, and capability to adapt.

Agronomy provides a plethora of near and longer-term solutions for smallholder farming systems to adapt to climate change, but there are no silver bullets or 'one size fits all' adaptation pathways. It is essential to understand the nature of the climate-based risks in specific regions and for specific farming systems as well as the social, economic, and technical resources that can be marshalled to effectively respond whilst addressing the barriers preventing farmers to adapt. Scaling up of agronomic adaptation measure may also have an important role to play in climate change mitigation, through reducing generation of greenhouse gases, and through co-benefits generated by sequestering carbon in soil with cascading benefits on soil moisture dynamics.

The CGIAR Excellence in Agronomy (EiA) Initiative established in 2020 and the Bill & Melinda Gates Foundation co-hosted a two-day convening event in Nairobi to clarify climate change related agronomy research priorities and partnership opportunities for the new initiative on EiA. The convening invited technical experts and thought leaders in the fields of climate change, agronomy, soil health, water, modelling, and agriculture policy. Technical experts were from research institutions, the scientific community, policy think tanks, private-sector, and multi-lateral institutions.

3. TWO-DAY CONVENE WORKSHOP OBJECTIVES

This meeting convened stakeholders across the agricultural sector to identify promising entry points for effective and scalable agronomic solutions for climate resilience without compromising food security, livelihoods, and environmental objectives. Specifically, the convening aimed to:

- Discuss the relevance of EIA's global climate framework and its adaptiveness to implementation in the different regions pending variations in perceived climate hazards and shocks requiring different sets of agronomic practices and solutions;

- Identify key research for development (R4D) questions to address identified gaps, and the necessary tools, methods, approaches, and partnerships needed to accelerate agricultural climate resilience at scale.

Specific inputs and feedback was collected around the following key learning questions from the convening:

1. How can EiA's approach to the identification and prioritization of climate adaptation solutions be rolled out in the different regions?
2. What are some of the methodologies and frameworks that could help EiA in monitoring the impact of climate adaptation?
3. What partnerships are key to ensure scalability of climate adaptation and mitigation action at scale?
4. What should be EiA's research priority in the climate adaptation and mitigation space?

The convening agenda can be found in Annex 2 and the slide deck in Annex 3. The following sections in the report describe the objective and outcomes of the sessions for each of the learning questions and identify the next steps for EiA.

4. CHALLENGING EIA'S CLIMATE LOGIC ON IDENTIFYING AND PRIORITIZING SOLUTIONS

The accelerating pace and severity of climate-induced impacts on global agricultural systems necessitates rapid and coordinated action to support sustainable development. At the same time, there is a growing recognition that universal 'climate smart' solutions for cropping systems do not exist. Context defines good agronomy, and effective responses to the climate change challenge are no exception. In the absence of a broad evidence-based consensus to guide action in most parts of the world, agricultural priorities are often set in an ad hoc manner that results in modest changes in systems resilience and longer-term adaptive capacity. Moreover, most existing priority setting exercises often lack rigor by generalizing the nature of the climate hazards, the effectiveness of different response options, or the challenges of bringing different solutions to scale. The sessions explored firstly the main prevailing climate hazards within the different geographical regions (East Africa, West and Central Africa, Latin and Central America, Central and West Asia, South and Southeast Asia) and took the participants through a prioritization exercise.

Overall, the session highlighted the complexity of identifying and addressing climate hazards in different agro-ecological contexts and cropping systems. The solutions that emerged were rather general, and there were valid questions raised about how to incorporate climate adaptation within the larger system of farming challenges such as livelihoods and sustainability and ensure that the solutions are suitable for farmers. To address these challenges, it will be important to identify the specific climate hazards and their impacts on different cropping systems and farmer segments, and to use data and information to support this identification.

The main climate hazards identified for multiple cropping systems (maize, rice, wheat, sorghum, millet, etc.) were related to drought, floods, increased temperature, new pests and diseases related to changing climates. Two hazards that so far have not been included in EiA's framework are hurricanes in Latin America and cold stresses in Western and Central Africa. In the absence of supporting data and specific information on climate hazards and cropping systems, the solutions proposed were rather broad. It reiterated the complexity of targeting solutions to address multiple climate hazards often occurring at different times but in the same geographic areas affecting the same cropping systems. The broad set of solutions across the various regions included climate resilient varieties (pest and diseases, drought, low nutrient requirements), climate advisory services (rainfall, planting date related to rainfall onset), crop insurance, improved infiltration-conservation agriculture, crop switching, and irrigation together with real-time monitoring, agroforestry, integrated packages (varieties, agronomic practices, farming system, climate risk), water management technologies (drainage, irrigation and rain water harvesting).

The participants also suggested that the process roll-out of soliciting solutions needs to be robust to avoid biases and solution pushes, and that identifying different technologies and innovations which have worked elsewhere and exploring their adaptability in new locations for similar climate challenges should be considered. By taking a systems perspective and involving a range of stakeholders, it may be possible to develop more effective and appropriate solutions for addressing the complex challenges of climate adaptation in agriculture.

In a follow-up session, the participants were exposed to EiA's prioritization framework and CAPTain (The Climate Adaptation Prioritization Tool – See Annex 3). EiA's proposed priority setting exercise for evaluating agronomic response options is predicated on the idea that consensus building processes will generate clearer priorities that will result in more focused and impactful research and development investments. The results of this exercise will guide EiA's regional priorities into its second business cycle and mobilize partnership networks with aligned interests. The main aim of the follow up session was to solicit feedback on the criteria and the prioritization process.

The participants have identified areas of improvement as it is essential to consider the different sub-sets of criteria, as they can significantly affect the overall score. It is great to see that the team is looking at the potential impact of the solution on different stakeholders, including farmers, agro-dealers, private sector, and the government. The discussion on the indicators revealed that each participant does have a different understanding of what the criteria entails. Acknowledging that they were given a "simplified" version participants felt that depending on the "sub-set" of criteria the solution bundle could be scored very differently. Reflections made on the criteria are given in Annex 4. Participants also noted that certain elements were missing in the tool such as the need, capacities were included in "Ease," and readiness was not accounted for unless the data systems existed.

Carrying out the prioritization exercise with the experts in the room also reaffirmed the need to be inclusive of all stakeholders when carrying out a prioritization exercise. Soliciting expert opinion remains a challenge and the results are highly biased towards who is in the room.

INSIGHTS FROM THE SESSION

- Climate change creates various hazards that manifest with varying degrees of intensity across different regions.
- While EiA is currently organizing its agronomic responses against 5 such hazards (drought, flood, climate variability, growing season reduction and heat stress) these categories are rather generic and may require a more specific description and interpretation at the regional level.
- The prioritization framework fills an important knowledge gap by formalizing priority setting through participatory processes and by providing a collaboration platform for learning and consensus building towards joint action.
- The framework increases decision-making transparency and 'makes the case' for targeted agronomic solutions that address the climate crisis.
- Expert facilitation and being inclusive will be essential to the success of prioritization workshops. Group composition will have a disproportionate influence on the outcomes of prioritization workshops; participants must be carefully selected, and more stakeholders consulted thereafter.
- Work to ensure that the questions in the prioritization framework are as clearly posed as possible; the tool was well-received but 'tightening' on some topics and indicators is required.
- Ensure that data related to climate hazards and effects on cropping systems is populated, to create an objective starting point for expert solicitation.

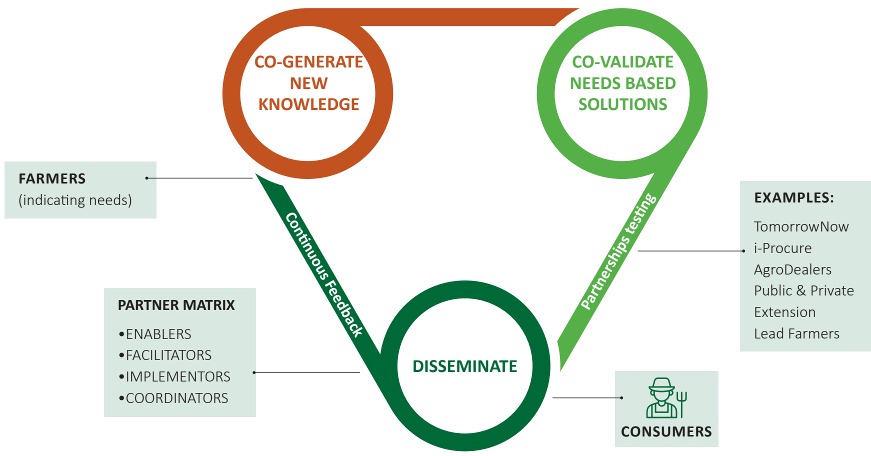
ACTION POINTS FOR EIA

- Improve the CAPTain tool by incorporating the convening participants' feedback – May 2023.
- Add default data layers to facilitate rollout and standardization – June 2023.
- There is no global playbook to address climate adaptation. EiA should identify common agro-ecological zones, climate hazards and crop production systems when rolling out its prioritization framework for climate adaptation – May 2023.
- Finalize EiA's strategy paper- June 2023.
- Develop an opinion piece in Nature Food and feed this into Cop28 by September 2023.
- Roll out the prioritization framework for agronomic interventions to support climate adaptation through the regions using the CAPTain tool and feed the results into the second business cycle: June – December 2023.

5. IDENTIFYING ENABLERS AND PARTNERSHIPS TO SCALE CLIMATE ADAPTATION SOLUTIONS

One of the core objectives of EiA is to bring agronomic solutions to scale using digital solutions that address farmers' needs. The session explored to what extent solutions that enhance climate adaptiveness of smallholder farmers would require additional enablers and innovative partnerships to accelerate scale. The group discussed the need for an adaptive framework with feedback mechanisms that capitalize on the different stakeholder needs and responsibilities. Especially in relation to climate adaptation solutions there is often a bundle of supporting enablers or services that need to accompany the agronomic practice to enhance adaptation. Think of the fertilizer application in each cropping system that requires weather services to enhance its nutrient use efficiency as soil is sufficiently moist and at the same time isn't too moist, so the fertilizer is washed away. In this scenario, a farmer's ability to adjust fertilizer application dates depends on several factors. These include having a partner who offers weather services, owning a mobile phone to receive the information, possessing literacy skills to understand the information, having the financial means to purchase the fertilizer, and ensuring that the fertilizer is readily available in the market.

Hence, continuous scanning of enablers and potential barriers for scaling the agronomic solutions is crucial. Therefore, the question is not so much who are the "missing partners" for climate adaptation, but which partners need to come in when, where and how. Partnerships are adaptive across the scaling process depending on altering geographies, new climatic hazards, and the risk perception of venturing in new markets. There might be partners that help with "kicking things off" and provide first investments whilst others are better placed to adapt it to a new geography. For example, the vast variety of climate services with country specific agencies provides a great platform to support standardization and roll out of EiA's climate related information services for specific cropping systems.



When talking about climate adaptation solutions with potential mitigation co-benefits it is important to not only look at these from a farmer perspective but also understand climate related risks to the actors facilitating the "enabling environment" which includes policy, agro-dealers and other value chain actors, credit and other financial institutions etc. The perception of climate related impacts on businesses might reduce the access and affordability of products that farmers need to acquire to adopt and implement agronomic solutions. Aside from risk perception, also ensuring alignment of mutual interests, business models and trust is important throughout the partnership process. How we effectively mobilize convergence between institutions requires an indepth understanding of incentives and disincentives for convergence.

1. The groups identified several specific partners in in the various regions that could support the R&D, scaling and advocacy of contextually relevant climate adaptive solutions. At global level the following recommendations were made for EiA to further advance across:Science and innovation: Strenghtening the collaboration with leading universities in the climate space (e.g. Rothamstead, Potsdam Institute for Climate Impact Research). Especially identify those that are cutting edge on the monitoring of impact of climate adaptation processes and research associated with climate risk perception and maladaptation.

2. Scaling delivery: Linking to larger programs funded by multi-lateral development banks such as the World Bank (e.g. AICCRA), make use of GCF and new private sector financing modalities for climate adaptation/mitigation

3. Advocacy: Feed results from EiA into the One CG Climate Platform and alliances usch as the Climate Resilient Food System Alliance (UNFCCC secretariat) coming out of the UN Food System Summit. This can be done by brining EiA into co-developed sessions with key partners.

Over the coming months it will be important for EiA to work with the Climate Platform to identify strategic partnerships to further advance the initiative's agenda on climate adaptation whilst enhancing its visibility globally.

INSIGHTS FROM THE SESSION

- Enablers are as important as practices and technologies: it is important to strengthen partnerships that support influencing key enabling levers to enhance the impact of climate adaptative agronomic practices. These enablers include influencing policy, markets, knowledge finance etc.

- Bundling of agronomic solutions with other socio-technological innovations, adapted to the broader enabling environment, is key to enhance smallholder adaptive capacity to climate change.

- Partnerships to reach scale require an understanding of their climate related risk perception, alignment of incentives and clear roles and responsibilities. Furthermore, partnerships can change across the scaling process depending on altering geographies, new climatic hazards, and the risk perception of venturing in new markets.

- Making the enabling environment more climate adaptive and conducive for scaling climate adaptation solutions are not core to EiA; engagement with other CGIAR Initiatives is critical to achieve impact.

- There needs to be a feedback mechanism established to evaluate partnerships across the scaling process.

- Advocacy is needed to bring socio-technological innovation bundles in agronomy closer to the climate adaptation discussions as there is often a lack of understanding regarding the potential actions that can be taken.

ACTION POINTS FOR EIA

- Use cases to apply adaptive management to partnerships and bundling of innovations to enhance climate adaptiveness of services provided – continuous throughout EiA's program.
- EiA to work with the Climate Platform to identify strategic partnerships to further advance the Initiative's agenda on climate adaptation whilst enhancing its visibility globally – December 2023.
- Develop a global narrative with the Climate Platform, highlighting the pivotal role of agronomy in climate adaptation – October 2023.
- Review methodologies to assess climate related risks and the related perception of partners are crucial to support scaling of EiA's solutions – March 2024.
- EiA needs to identify how climate related risks influence the enabling environment and potentially hamper agronomic solutions from going to scale – framework will be developed in 2024.

6. MEASURING AND MONITORING CLIMATE ADAPTATION

Core to the implementation of EiA's agenda on climate adaptation is the ability to monitor the impacts of climate adaptive agronomic interventions at farm, household and landscape level. The participants in the measuring and monitoring session discussed how to track adaptation and measure change.

They started by identifying practices that are adaptive within a given system and ways for collecting primary data about people practicing these options. It was suggested that existing survey data, such as LSMS-type surveys, can be useful in identifying processes associated with behavior change and factors associated with adaptive change. Remote sensing information or exogenous datasets can be brought in to measure and identify climate shocks. The group suggested that a cost-effective and robust way to measure and monitor adaptation is to build a set of standard indicators linked to spatial data within the landscape where the projects are being implemented.

They emphasized that it's important to capture both the means and the ends of the adaptation process, i.e., whether people are using adaptive practices and whether those practices are achieving the desired outcomes.

The group also discussed the importance of distinguishing between anticipatory and curative adaptation measures and the need to capture data at both the farm and household level. They suggested that it may be useful to look at how other sciences approach the issue of measuring change and adapting these methods to the agronomic context.

There was some discussion of the trade-offs between adaptation and other objectives, such as intensification, and the need to be explicit about these trade-offs in context-specific ways. The group also noted the importance of testing the climate robustness of interventions with data and models and capturing crop-by-weather data using remote sensing methods.

The group discussed the plethora of tools and frameworks that exist for monitoring and measuring adaptation and resilience, and some of the challenges associated with them. They noted that many existing frameworks are data-intensive, which can be a challenge in shorter duration programs. Ultimately, they concluded that there isn't one framework clearly ready for use by EiA and it should be a priority for 2023 to develop a suitable framework.

INSIGHTS FROM THE SESSION

- Many frameworks are available. However data requirements make them unsuitable for EiA.
- There is a need for streamlining approaches to evaluate technical agronomic practices and their impacts on climate adaptation building upon earlier efforts (e.g.; ERA).
- Tracking adaptation for agronomy represents an important new area of research and while many of the technical ingredients are available, practical frameworks will need to be developed and validated to serve the agronomic community going forward.
- Tracking adaptation requires linking bio-physical to behavioral change, socio-economic frameworks and cover various spatial and temporal scales. EiA's adaptation framework needs to also relate to sustainability, given the program's scope.
- Long-term experiments are needed to generate the necessary data on potential for climate adaptation; to be combined with modelling tools.

ACTION POINTS FOR EIA

- Develop a consolidated workflow to assess the climate adaptiveness for use cases and their MVP – Oct 2023.
- Develop a monitoring framework and practical tools to monitor the impact of EiA's practices along the adaptiveness spectrum including its interaction with the environment – March 2024.

7. STRENGTHENING EIA'S FUTURE RESEARCH AGENDA ON CLIMATE ADAPTATION

Research at the intersection of agronomy and climate change exists, but it is so far not framed from an agronomic standpoint. This is by necessity, rather than by strategy, since most research at this intersection has focused on generating evidence about climate change impacts in response to the Intergovernmental Panel on Climate Change (IPCC). Accordingly, most research has been framed almost exclusively from a climate adaptation standpoint. For example, most future projections of climate impacts on crops focus on crop yield (a key measure for agronomic gain). Likewise, most adaptation studies analyze shifts in agronomic management including planting dates, cultivars, and fertilization, as keyways of adapting cropping systems to climate change. Yet virtually no studies explicitly address the intersection of climate adaptation and (sustainable) intensification. This highlights substantial opportunities for the Agronomy Community to identify and address opportunities and knowledge gaps within the next decade.

The discussion groups on **knowledge and research gaps** covered a wide array of topics. These included methods to link hazards to agronomic solutions, to the economic value of climate prediction for agronomic decision making. Some of the key themes that emerge from these questions included:

- **Linking sustainable intensification and climate adaptation**:
  A key overarching question was related to developing an adaptation agenda within the sustainable intensification agenda. We need to understand where and how it fits, as the question of whether it fits is not particularly relevant in the context of changing climate conditions. What is the entry point for climate adaptation within the agronomy space? Tradeoffs between sustainable intensification and climate adaptation also need to be explored.

- **Linking hazards to agronomic solutions:**
  Climate models need to be evaluated for precision vs accuracy as climate models do not address shocks to agricultural systems. There is a need to understand how different levels of stress and compounding effects impact agronomic solutions, and what methods are available to link hazards to specific solutions. This includes exploring whether systems can be created that account for various levels of stress, and whether agronomy is effective for high stress systems. A related discussion was about the use of climate homologues and analogues to identify future environments and test options.

- **Adoption and tradeoffs:**
  This requires understanding the adoption limits for different agronomic practices, and what factors impact adoption, such as perceived risk and water insecurity.

- **Data and information:**
  This relates to how to deliver consistent information on climate change and adaptation across different levels, and how to use data to enhance the uptake of advisory services. The economic value of climate prediction for agronomic decision making is also an important consideration. Data ownership and service creation need to go together. There is a need to explore the responsible use of Artificial Intelligence (AI) in relation to influencing behavioral change, and the ability to explain model-based results.

- **Transformational adaptation and risk management:**
  There is a need to understand how to approach transformational adaptation given high uncertainty in climate risk markets and other conditions related to timescales. Additionally, the place of risk management beyond agronomy in supporting successful adoption and scaling needs to be explored.

- **Linking/connectivity:**
  Link farm systems and landscapes to support resilience and adaptation. This includes exploring gaps in crop modeling for specific crops and identifying knowledge gaps. How does EiA engage in landscape-related (e.g., water mgt) vs. farm/field level interventions in the adaptation space?

These research questions highlight the complexity of the issues related to agronomy and climate change adaptation. Addressing these questions will require collaboration across disciplines and sectors, as well as a focus on understanding the tradeoffs and potential unintended consequences of different solutions.

The discussion on disruptive innovation covered several topics related to innovation in agriculture and climate change adaptation. Participants discussed:

- The importance of innovation in remote sensing, particularly with respect to environmental variables. The potential benefits of new satellite and radar technology for measuring rainfall at high spatial and temporal resolutions were highlighted. Participants also discussed better integration of remotely sensed vegetation into real-time monitoring systems for smallholder farming systems.

- The need to learn from innovation and methodological approaches in the food security community, such as those used by the Famine Early Warning System Network (FEWS Net) for use of climate predictions at different timescales. There is much progress to be made by the agronomy community if it were to capitalize on these learnings. Likewise, the agronomy community should look at the Medical Research Community about data accessibility, transparency, sharing, to enable R&D processes.

- The potential of bots and language processing to enhance accessibility to data and insight, but also the need to tailor these technologies to the smallholder context.

- The ethics and responsible use of technology and AI to influence farmer behavior. This emphasized the importance of transparency and data privacy, and responsible use of AI technologies.

- The concept of data ownership and privacy, and the potential for a "data wallet" for each farmer to enable them to select the services of greatest interest and value. This is as opposed to a supply driven provision of services.

Overall, the session explored ways to leverage technology and innovation to drive positive change in agriculture and climate change adaptation while being mindful of ethical considerations and the needs of smallholder farmers.

The notes from the session on Moonshot ideas highlight a range of innovative and potentially transformative ideas related to agronomy and climate change adaptation. Some of the key themes that emerge from these ideas include:

- **Finance and carbon credits:**
  There are potential opportunities to leverage finance and carbon credits to support sustainable integrated farming practices and to generate income for farmers. For example, one idea proposes that EiA could generate 1 billion USD from carbon credits for farmers.

- **Innovation and technology:**
  Accelerate the adoption of agronomy through innovation and technology, including vertical farming and accelerating mechanization. Another idea proposed to have 1 million tech-savvy professionals driving extension and advisory services by 2025.

- **Rethinking farming and diversification:**
  Rethink farming practices and explore alternative non-farm livelihood options. Crop replacement and diversification could also increase farm income by 30%.

- **Thresholds and hard questions:**
  Investigate radical shifts and explore hard questions related to agronomy, including peri-urban agriculture and food waste, and whether agronomy is being used effectively for climate adaptation. Thresholds for land sizes where climatic adaptation makes economic sense need to be explored.

- **Environmental services:**
  There are opportunities to leverage the energy sector to finance ecosystem services, such as linking carbon waste to soil, and to explore new forms of agriculture, such as growing insects and seaweed in degraded, climate untenable locations.

These moonshot ideas highlight the potential for transformational change in agronomy and climate change adaptation. While some of these ideas may be ambitious or challenging to implement, they provide important opportunities for collaboration and innovation to address the complex challenges facing agriculture and the environment.

INSIGHTS FROM THE SESSION

- Research is needed to unpack how climate change affects sustainable intensification pathways, how technologies and technology bundles respond within systems experiencing climate stress. Additionally, it is crucial to examine the barriers faced by smallholders in adopting adaptation measures. Moreover, exploring the trade-offs and synergies between adaptation and sustainable intensification is essential.

- A priority research issue relates to changes in the agronomy R&D systems that are necessary to understand and address climate adaptation needs. We need to evaluate climate-related impact on yield gaps and use data from existing long-term experiments to evaluate adaptation potential of key agronomic practices (e.g., analyze system performance in stressful or extreme years). Likewise, the agronomy community should design experiments to evaluate agronomic adaptation interventions with a focus on future climate conditions, making use of climate analogues and homologues approaches.

- The agronomy community must maximize the utilization of climate predictions. This entails assessing their effectiveness, enhancing their accuracy by calibrating and rectifying biases, adjusting them to the suitable spatio-temporal resolution for making agronomy-related decisions, and integrating them into agronomic advisory services. The agronomy community should review the experience of the Food Security and Famine early warning community as a starting point.

- Disruptive innovation is possible especially with regard to environmental and farming system monitoring (leveraging earth observation), data ownership, and (positively and responsibly) influencing farmer behavior. Several disruptive technologies are already available that EiA can leverage into agronomy R&D processes in various use cases.

ACTION POINTS FOR EIA

- Develop a targeted R&D agenda for the second business cycle to enhance EiA's climate adaptation agenda – December 2023.
- Develop strategic partnerships with key research institutes and renowned climate science experts – continuously through the EiA program.

ANNEX 1

THE VERSION OF THE STRATEGIC PAPER CIRCULATED PRIOR TO THE CONVENING

Agronomic adaptive strategies to strengthen smallholder farmers' resilience to climate change

Todd Rosenstock[1], Petra Schmitter[2], Peter Steward[1], Julian Ramirez-Villegas[1,3], Sieglinde Snapp[4], Andrew McDonald[5], Camila Bonilla-Cedrez[3], Marc Corbeels[6], Tafadzwa Mabhaudhi[2], Elliot Dossou-Yovo[7], and Bernard Vanlauwe[6] on behalf of the *Excellence in Agronomy 2030 Initiative*

[1] Alliance

[2] IWMI

[3] WUR

[4] CIMMYT

[5] Cornell

[6] IITA

[7] Africa Rice

The acceleration of climate change calls for immediate action to scale solutions that increase the ability of small-scale farmers to adapt and make farming systems more resilient. Agronomy provides opportunities to achieve these goals. This paper explains the key concepts that are crucial to identifying the limitations and potential of agronomy in relation to climate change adaptation. It also explores how, when, and where agronomy can be used effectively and how to scale adaptable agronomic solutions. We first outline the general patterns of farmer exposure to climate hazards. Next, we demonstrate how agronomic innovations reduce climate risk, help farming systems in recovering from climate shocks and empower small-scale producers to respond to production challenges. Thirdly, we provide a practical classification of agronomic adaptation options and explore how delivery on climate adaptation requires strengthening implementation modalities such as partnerships and monitoring and evaluation. Finally, we identify a set of research questions to guide the Excellence in Agronomy 2030 Initiative's impact strategy.

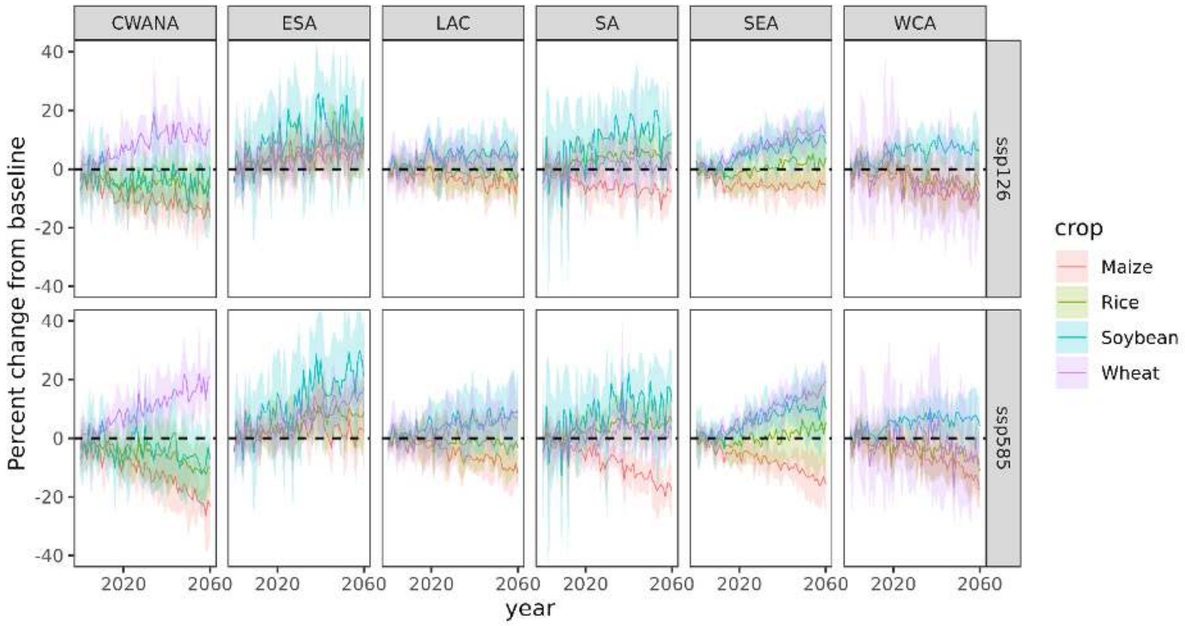
Climate change is already affecting agricultural production in various ways, such as shorter growing seasons, irregular rainfall patterns, rising temperatures, increasingly frequent heat waves, droughts, and floods (Raymond et al., 2022; Wiebe et al., 2015). These conditions negatively impact crop growth and agricultural productivity. Estimates suggest climate change has reduced yields of maize, rice, and wheat by -5.8%, -3.1%, and -2.3%, respectively in Sub-Saharan Africa and by 1.0%, -0.8%, and -0.9%, respectively in Western, Southern, and Southeastern Asia between 1974 and 2013, conditions responsible for a 1% reduction in calories across ten major crops (Ray et al., 2019). Another analysis indicates that the aggregate effects of climate change have reduced total factor productivity—a key economic measure—by an estimated 20% globally and up to 40% in Africa and Asia since 1961 relative to a world without climate change (Ortiz-bobea et al., 2021). The decline in productivity is a significant concern since increasing productivity is the main strategy to meet the world's growing food demand (Fuglie, 2018), while also avoiding negative consequences such as biodiversity loss, water insecurity, and greenhouse gas (GHG) emissions caused by expanding agricultural frontiers.

Extreme weather events have the potential to cause especially catastrophic losses. Typhoons in Madagascar destroy the rice crop, heat waves in India reduce wheat production, or droughts in the Horn of Africa devastate maize yields are a few examples. Disaster-related losses to agriculture totaled 12 billion in 2019 alone, with losses in low- and middle-income countries estimated at US$108 billion between 2008 and 2018 (FAO, 2021). Eighty-two percent of the medium-to-largescale natural disasters over the past ten years were absorbed by agriculture, 82% of them were droughts. The magnitude of current productivity losses, both from changing average conditions and extreme events, demonstrates profound current impacts and foreshadows the years ahead.

The latest crop models also indicate substantial future risk. Projections suggest that maize yields between 2069 and 2099 will be 24% and 6% lower than they were between 1983 and 2013 under high and low GHG emission pathways, respectively, with significant impacts arising sooner (Fig. 1) (Jägermeyr et al., 2021). In contrast to maize, global rice, soybean, and wheat production are generally projected to increase, in part because of rising carbon dioxide (CO2) concentrations, though benefits of elevated CO2 may be more moderate than models suggest given drought, nutrient, and other growth constraints. However, estimates of average global impact can mask significant regional variation. For example, maize losses are expected to be more severe and widespread in tropical regions (Jägermeyr et al., 2021) while rice yield is projected to decrease by 24% in Africa (van Oort and Zwart, 2018). The impacts may be amplified as crop production relies heavily on a narrow set of highly vulnerable regions and staple crops. Studies typically model only a handful of staple crops, yet climate change will have broad effects across cropping systems, including those important for nutrition such as leafy vegetables, pulses, and tree fruits (Carr et al., 2022; Yang et al., 2020) as well as internationally traded commodities such as coffee (Kath et al., 2020; Requena Suarez et al., 2019). These projected agricultural climate challenges contrast starkly with projected food demand, which is anticipated to increase from 2010 levels by at least 35% by 2050 (van Dijk et al., 2021)

FIGURE 1. CLIMATE IMPACTS ON GLOBAL REGIONAL CROP PRODUCTION.

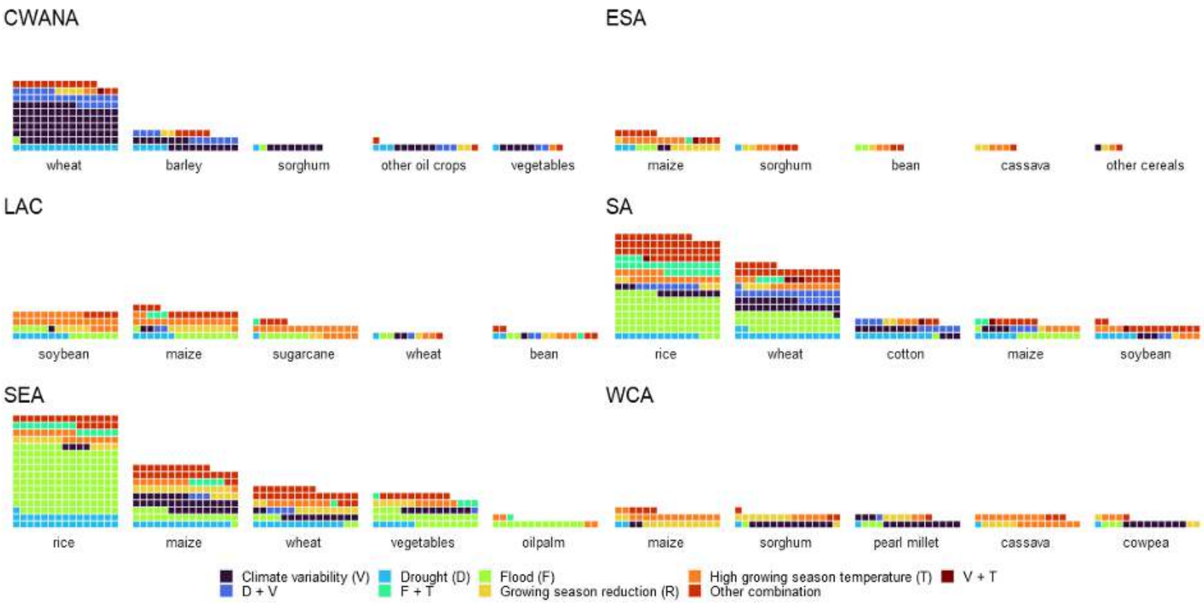
Projected changes in productivity against baseline figures (1983–2013) under low emissions (SSP126) and high emissions (SSP585) scenarios, according to the CMIP6 model by region (data from Jägermeyr et al., 2021). Abbreviations for regions: Central and West Asia and North Africa (CWANA); East and Southern Africa (ESA); Latin America and the Caribbean (LAC); South Asia (SA); Southeast Asia (SEA); West and Central Africa (WCA).



Climate hazards are multiple and multiplicative, with the type, frequency, and magnitude varying across regions and within countries over space and time. These hazards cannot always be reliably predicted or forecasted, posing serious challenges for farmers and policymakers. Examining regional, national, and local climate risks provides a clear understanding of what is at risk and the factors most likely to impact cropping systems (Jarvis et al., 2021) (Figure 2). For example, rice in Southeast Asia is exposed to greater risk of flooding, while rice in South Asia and West Africa is likely to experience a combination of multiple hazards, including floods and droughts. Jarvis et al. (2021) estimates that the aggregate annual production at risk from exposure to rainfall variability, drought, high temperatures, and growing season reductions is valued at US$246 billion in Central, West Asia, and North Africa (CWANA). In South Asia and Southeast Asia, climate hazards threaten production systems valued at US$194 billion. In Sub-Saharan Africa, production systems covering 297 million hectares and valued at US$114 billion are exposed to climate hazards annually. Rainfed agriculture often faces challenges when floods and drought occur in the same location and even within the same cropping season. In Latin America and the Caribbean, production systems valued at US$295 billion are exposed to climate hazards. Though it is difficult to map multiple hazards occurring at the same location, the top five hazards relate to water-induced crop stress, high temperatures, shortening growing seasons due to early or late rains, unseasonable variability, drought, and flood puts US$97 billion in production annually at risk. Exposure of this magnitude threatens global food security.

FIGURE 2. REGIONAL EXPOSURE TO CLIMATE HAZARDS TO THE TOP FIVE CROPS REGIONALLY.

Risks would show spatial correspondence between climate hazards and cropping locations. Abbreviations for regions: Central, West Asia, and North Africa (CWANA); East and Southern Africa (ESA); Latin America and the Caribbean (LAC); South Asia (SA); Southeast Asia (SEA); West and Central Africa (WCA). Each square equals 100,000 ha. (Agriculture Adaptation Atlas, unpublished).



When considering global and regional climate impacts, it is easy to lose sight of the implications for small-scale farmers. Globally, there are over 608 million smallholder households (Lowder et al., 2016; Mason-D'Croz et al., 2019), which amounts to about 40% of the global population. These families produce about 30% of the world's food using about 25% of the world's cropland (Herrero et al., 2017; Ricciardi et al., 2018; Samberg et al., 2016). This cropland represents many people's primary source of food and nutrition security and income (Frelat et al., 2015). Productivity losses can trigger asset sales, loan defaults, lost education, food rationing, and natural resource degradation (Hansen et al., 2018), which have cascading effects, especially for those farming land only marginally suited for agriculture, as those most vulnerable are highly unlikely to recover. Without adaptation, food security, health, and farmers' livelihoods are at risk (Springmann et al., 2016; Vicedo-Cabrera et al., 2021; Wheeler and von Braun, 2013). Beyond the negative impacts in rural areas, climate shocks to agricultural systems are also a primary driver of unplanned migration to urban centers in the poorest countries (Falco et al., 2019). This dynamic can create new forms of poverty and overwhelm infrastructure. The extent of the challenge requires broad agreement on the urgency to adapt cropping systems.

2. ADAPTATION REQUIRES REIMAGINING AGRONOMY

Agronomy can improve the biophysical resilience of cropping systems, making its potential contribution to smallholder adaptation unequivocal. By design, agronomy controls how crops experience their environment and provides tools for farmers to adapt to environmental changes such as weather extremes. In doing so, agronomy represents a direct way for farmers to buffer climate change risk and moderate crop vulnerability (Hansen et al., 2018). An example of agronomic adaptation against drought is using mulch, reduced tillage, water harvesting, and increasing duration of plant cover to enhance water infiltration, which offers a net benefit of conserving soil moisture, reducing the impact of short-term droughts and dry spells (Belay et al., 2020; Komarek et al., 2021). Intercropping and mixed cropping systems may help to efficiently use soil moisture by differentiating niches for various plants' roots, improving water infiltration, and buffering crop water requirements (Renwick et al., 2020; Snapp et al., 2010). Supplemental irrigation can sustain production during intermittent and longer-term droughts, lasting months, but these scenarios may require more investment and systemic changes in agronomic systems such as shifting to a different crop or investing in infrastructure (Balwinder-Singh et al., 2019).

Another example of agronomy's potential relates to managing unseasonable weather variability that combines both droughts and floods. Two locations with the same total rainfall may experience vastly different rainfall distribution patterns. In some cases, this means too much rain at once or at the wrong time, harming crop development. Likewise, some areas experience substantial year-to-year and within-year variations, with total rainfall sometimes differing by an order of magnitude between 'good' and 'bad' years. Agronomy, such as modifying planting dates, can help align crop growth with the necessary rainfall and temperatures (Lana et al., 2018; McDonald et al., 2022). Agronomy's adaptation benefits are not limited to water-related risks; farmers' choices, such as agroforestry and variety selection can reduce the impacts of rising temperatures and extreme events in some cases (Antwi-Agyei et al., 2018; Sida et al., 2018).

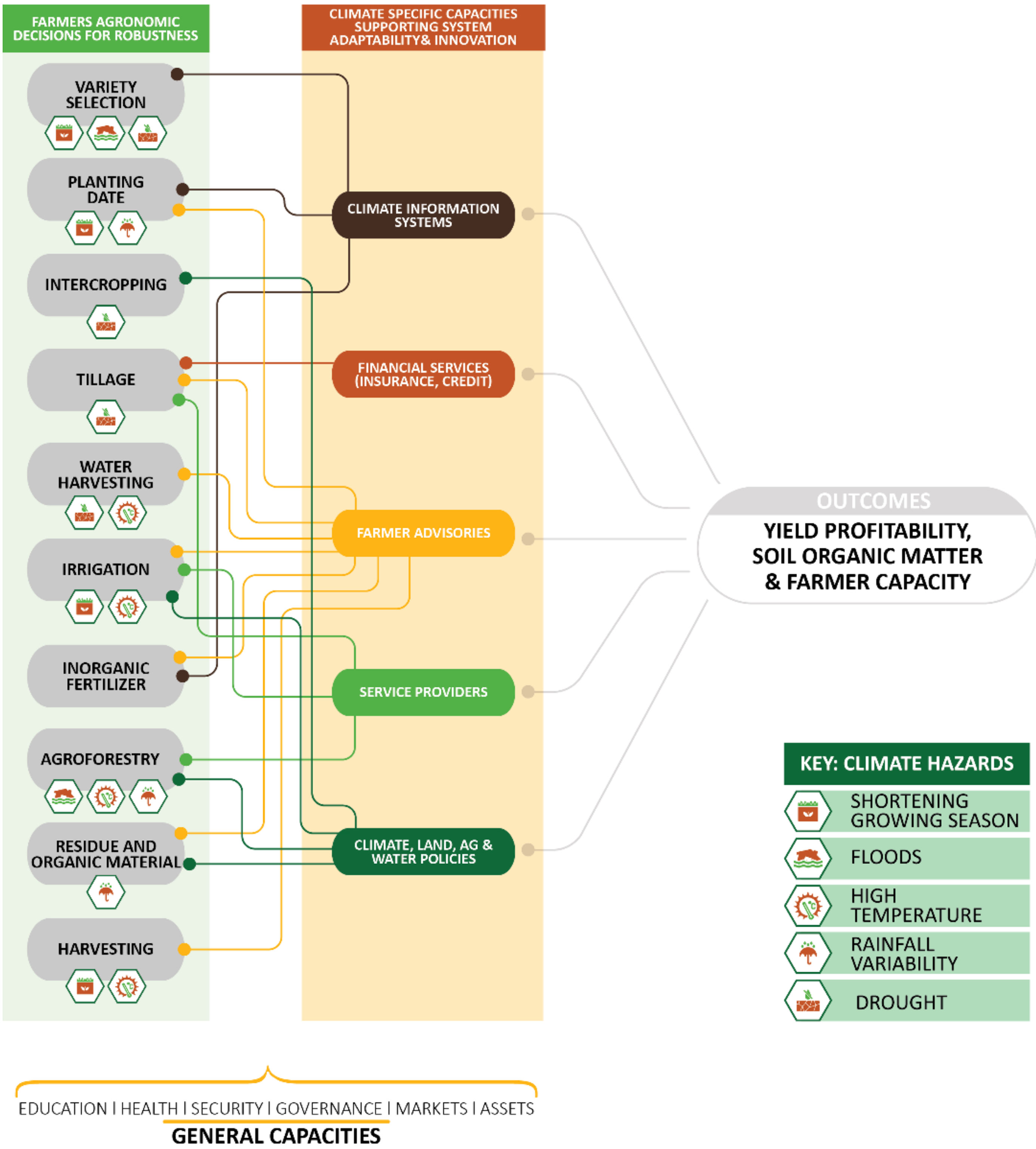
However, it is not enough to develop and make available agronomic practices that mitigate climate risks. Only 1 to 29% of farmers in ten African countries have adopted new agronomic practices (Stevenson et al., 2019), despite decades of investment in research, development, and extension. Agricultural adaptation will require millions of farmers to continually modify how they manage their fields in response to progressive climate changes, and increased climate and weather variability. Shifts in practice and farmers' response readiness are already necessary in many regions. These shifts will generally intensify with time, and current capabilities are both uneven and generally inadequate. Since resilience is the result of farmers' capacities to adapt, cope with shocks and make transformative changes in farming systems and livelihood strategies, new strategies are needed to speed transitions to adaptive agronomy.

Understanding that agronomic practices are part of broader innovation systems—including value chains, policies, extension messaging, knowledge, and skills is essential to overcome adoption barriers and to build long-term adaptive capacity (Fig. 3). Even seemingly minor management changes necessitate measures beyond the farmer's control. For example, changing planting dates requires weather forecasting, easily understood and relevant delivery to farmers, flexible labor availability, a functioning market with minimal price volatility, timely availability of seeds and other agronomic inputs, and access to finance. This example illustrates that changing agronomic management must often be predicated on strengthening the enabling environment.

Evidence shows that bundling agronomy with interventions that improve the enabling environment support farmer adoption and adaptation at scale. For example, combining climate information services, crop insurance, and climate-adaptative seeds can help farmers bounce back faster and enhance productivity in the face of climate hazards (Kumbhat et al., 2020). Social learning through peer groups raises trust in climate information and awareness of adaptation options and in Senegal, social learning improved the uptake of climate adaptive agronomic practices, increasing productivity (Blundo-Canto et al., 2020; Chiputwa et al., 2019). Another example from India shows that fee-for-service services may reduce barriers to adopting capital-intensive technologies like zero tillage when farmers are resource constrained (Keil et al., 2017). As the service markets mature, social inclusion for smallholder households may also increase (Keil et al., 2019). When conditions are conducive, the private sector can provide further assistance. Hello Tractor, an Uber for Tractors in Kenya, facilitates mechanization to help the timing of field operations. Thus, adaptive agronomy must focus on both strengthening small scale producers' agency and food system flexibility and not only on the management practices themselves.

FIGURE 3. AGRONOMY SUPPORTS SMALLHOLDER ADAPTATION.

Each agronomic decision gives farmers an entry point to reduce crop vulnerability to climate hazards. Options are available and specific to farmers operating within diverse contexts and constraints. Enhancing farmer capacities with climate-specific and more general capacities facilitates uptake and innovation (adaptation) that increases and stabilizes location productivity. Over time, some adaptations can enhance water retention and boost soil health.



Adaptive agronomy is not without risk. Programs may unintentionally increase small-scale producer vulnerability, known as maladaptation (Eriksen et al., 2021),redistribute or create new sources of vulnerability. Four mechanisms drive these maladaptive outcomes: (i or exacerbate existing inequalities. For example, digital agronomy may benefit those have access to mobile phones but leave out large segments of the most vulnerable populations who do not have access to phones (Mehrabi et al., 2020) or are not technologically literate, further reinforcing their relative vulnerability. Additionally, there may be tradeoffs with future vulnerability. For example, scaling solar powered irrigation today may lead to unsustainable short-term choices such as groundwater depletion that threaten future resource access if water governance is missing (Pavelic et al., 2021). The risk of maladaptation has not been formally considered in agronomy programming previously. Future efforts may need to consider emerging frameworks for predicting and minimizing the impacts (Bertana et al., 2022).

The constraints to adoption and potential for maladaptation highlight the need for matching and prioritizing practices and interventions to specific production contexts to successfully scale them. Attempting to broadly scale certain technologies without considering differences in farming systems, farmers perceived risks, and the environmental conditions will likely fail. This approach will ensure that the chosen practices are suitable to socio-economic, agricultural and environmental conditions present in the area. Notably, both climate change and socioeconomic progress imply that the context is constantly changing. Efforts to predict which solutions work and can be scaled, such as with the Evidence for Resilient Agriculture (Arslan et al., 2022; Rosenstock et al., 2015), should be combined with deep engagement with farmers, public and private sector to avoid dead ends.

BOX 1. ADAPTIVE AGRONOMY'S MITIGATION OPPORTUNITY

Changing agronomic practices alters water and nutrient cycling, soil properties, and microbial activity, which in turn affects GHG fluxes and cropland carbon. For example, techniques such as periodic drainage of flooded rice systems (Liang et al., 2016; Oo et al., 2018), precision management of organic and inorganic fertilizers (Linquist et al., 2012; Tesfaye et al., 2021), planting trees (Feliciano et al., 2018; Kim, Dong-Gill et al., n.d.), using renewable energy, and conservation agriculture (Dossou-Yovo et al., 2016) can reduce emissions and increase carbon storage while maintaining or increasing productivity.

In theory, agricultural intensification can also reduce the conversion of forests and peatlands to farmland, which is a significant source of land-based emissions (Carlson et al., 2016; Carter et al., 2015; Waha et al., 2020). However, it is important that intensification is accompanied by strong governance to prevent increased resource exploitation, and pollution. With 12% of annual GHG emissions resulting from crop production (Xu et al., 2021), agronomic adaptation offers a way to help mitigate climate change (Smith et al., 2020).

3. ENTRY POINTS FOR AGRONOMIC ADAPTATION

The challenge in using agronomy to adapt lies in how to prioritize, sequence, and scale agronomic interventions in the context of specific production ecologies. This is difficult because the options available to farmers and their capacity to implement them varies (Aguilera et al., 2020)generating an extremely rich heritage of traditional knowledge; however, it is particularly threatened by climate change, including a higher than average warming and more frequent extreme climate events. The vulnerability is enhanced by the other components of global change affecting the Mediterranean basin, including biodiversity loss, freshwater overuse, disrupted nutrient cycles, soil degradation and altered fire regimes, in a context of high population density, water scarcity, high dependence on biomass and energy imports, and the prevalence of highly specialized, low diversity agroecosystems. Due to the need to create resilience to these interconnected threats, systemic adaptation measures are urgently needed. This review shows that this systemic approach can be provided by agroecology, which offers a holistic framework enabling the recovery and assessment of traditional knowledge and the cocreation of new local knowledge for enhancing resilience. It also highlights the role of the reconnection of food production and consumption, associated with the recovery of the locally-adapted, largely plant-based Mediterranean diet. Three types of complementary adaptation strategies for crop production are identified: (i. 'Typologies' can reduce complexity by classifying options, identifying entry points, and informing priorities. Existing typologies of adaptation options have categorized solutions by factors such as climate hazard, spatial scale, the degree of change required, whether they are proactive reactive, and whether they are technological, institutional, or behavioral (Smit and Skinner, 2002). Some also categorize options according to their mode of action, whether they reduce vulnerability, enhance resilience, or target specific risks (Eakin et al., 2009), or even more parsimoniously, whether options decrease impacts or increase capacities (Vermeulen et al., 2013). However, existing typologies do not fully address the degree to which solutions 'buffer' smallholders' climate vulnerability and the critical supportive components required for action at scale.

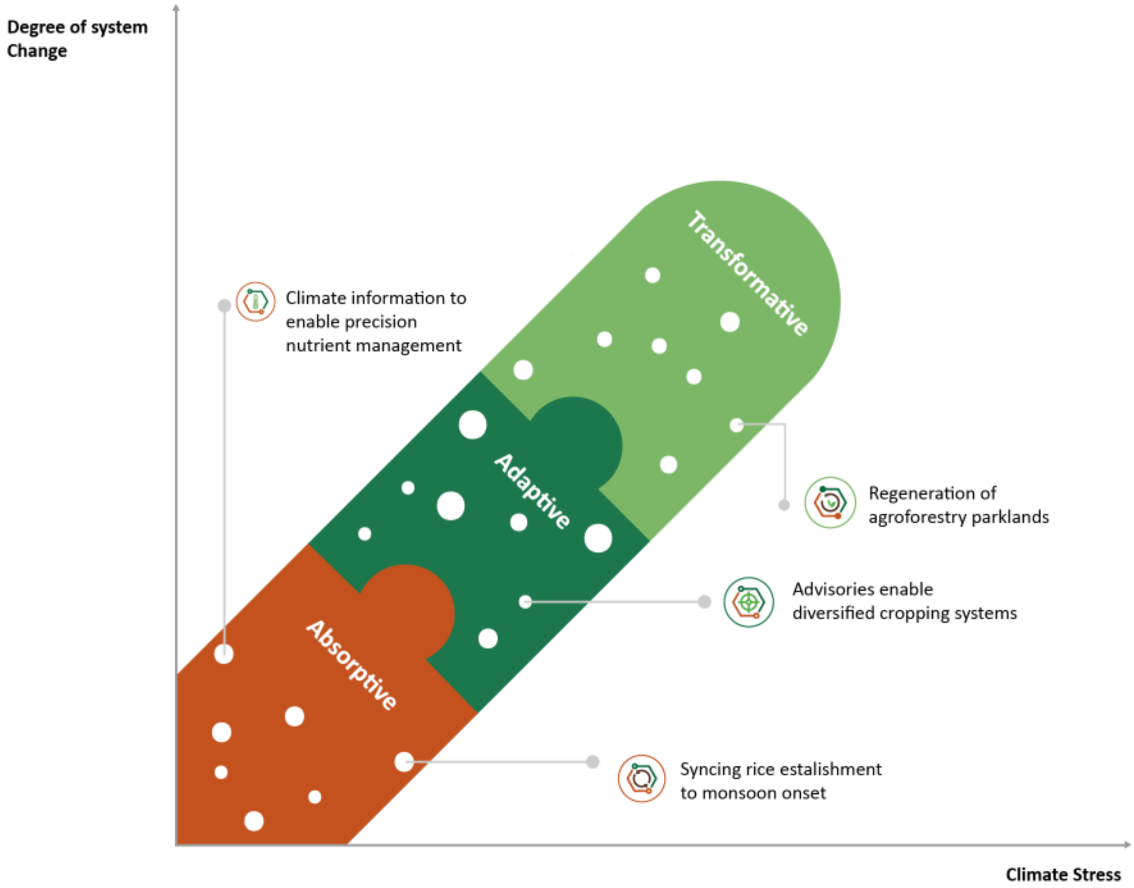
EiA's typology builds on earlier efforts that identify actions to cope, adapt, and transform, classifying options according to the degree of farming system change required and the level of climate stress for which the options are relevant (Fig. 4). Options include agronomic practice and crucial necessary enabling actions beyond the field boundary. For example, climate information and forecasts to optimize planting decisions. For relatively minor, already occurring climate-induced risks, adaptations that help absorb system perturbations are required. These include small changes in agricultural practices that build the robustness of the current cropping system such as revising planting calendars, planting stress-tolerant varieties, soil mulching, enhancing nutrient cycling and soil health, water-saving techniques, low-cost micro-scale irrigation technologies, and crop insurance. Absorptive actions help sustain production and incomes without fundamentally changing the farming systems' structure. The relatively minor degree of system change should not be confounded with magnitude of impact. Substantial gains in resilience and system performance can be achieved with absorptive measures.

For more severe climate stresses, which are likely to become increasingly frequent in the longer term, transitional and transformative actions are needed. Transitional actions modify the current farming system. They help farmers adapt to climate change by developing additional production and income streams often representing transitions into new products and markets. Diversification spreads climate risk and reduces the likelihood of complete crop failure helping maintain livelihoods despite adverse conditions. In addition to reducing risks and opening new markets, government safety nets that have been developed in the event of total crop failure also aid in maintaining systems under elevated stress.

Meanwhile transformative actions move farmers into new livelihood systems. Transformative actions become necessary when production of a crop is no longer viable due to climate stress. For example, farmers in India's Kasmir Valley shifted from cereals to tree crops such as apples and almonds in response to shorter winters and weather-related crop damage (Vermeulen et al. 2018). Increased rainfall in the Sahel has facilitated expansion of trees on farms. In other cases, transformative actions maintain productivity by shifting the growing areas to new regions (Sloat et al. 2020) or developing new resource systems such as large-scale water infrastructure that modifies the landscape to retain or enhance ecosystem services. However, alternative livelihoods are not always available or locally desirable. Transformation may require transitions out of agriculture all together with significant consequence for traditional knowledge, culture, and well-being.

FIGURE 4. EIA'S AGRONOMIC ADAPTATION TYPOLOGY.

Many agronomic solutions are available that can respond to near-, medium-, and long-term climate change risks. Several examples are highlighted to illustrate the degree of change required. Note that the baseline level of effort is high for system change, as even minor changes require many enablers to be in place.



Categorization of adaptive agronomic options according to the degree of farming system change required and the level of climate stress mitigated provides a high-level understanding of agronomic adaptation opportunities but not an operational model. To address this, each agronomic practice or combination of practices (the what) is then considered against the risk(s) they address (the why) and bundled with the factors and capacities enabling adoption and/or innovation (the how). For example, supplemental irrigation can mitigate maize yield reductions due to the climate risk of intra-seasonal drought in semi-arid Africa and requires the presence/development of a pump supply chain, farmers' access to credit, groundwater, extension services, and more. EiA's what, why, and how framing—which combines biophysical resilience attributes and social process—serves three purposes. One, it helps ensure that actions explicitly consider both the climate and local context. Two, it specifies the impact pathway for scaling adaptation options and outline entry points for investment in specific systems (Table 1). Three, it provides the basis for context-specific participatory priority setting by establishing the benefits, costs, reliability, and feasibility of actions.

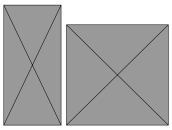
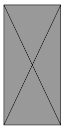
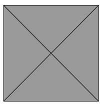
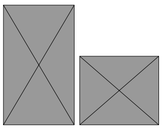
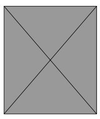
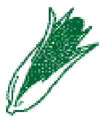
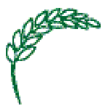
TABLE 1. SELECT EXAMPLES OF EIA'S TYPOLOGY ACCORDING TO THE TYPE OF HAZARD, CAPACITY, AND ACTION.

An extensive catalogue of system and location-specific adaptation options will be developed to quickly identify potential climate-explicit agronomic options when evaluating EiA Use Cases.

HAZARDS:

- Drought
- Flood
- Unseasonable climate variability
- Shortened growing season,
- High temperatures during the primary growing season.

CAPACITIES:	LEVELS:
I=Information,	● High
F=Finance (resources)	● Medium
T=Technology	● Low

TYPE OF ACTION	HAZARDS	EXPOSURE		CAPACITIES			AGRONOMIC PRACTICES & PRACTICES BUNDLES
	Drought, Flood, Unseasonable climate variability, Shortened growing season, High temperatures	CROP	LOCATION	I	F	T	
Absorptive	Drought, Flood, Unseasonable climate variability, Shortened growing season	 Cereals, roots & tubers	Global	High	Low	Medium	Climate information for planting time and variety decisions
Absorptive	Drought, Unseasonable climate variability, Shortened growing season	 Cereals	West Africa	Low	Low	Low	Alternate wetting and drying
Absorptive	Drought	 Rice	West Africa	Medium	Low	High	Mulch, climate advisories for planting and harvesting timing
Absorptive	Drought, Unseasonable climate variability, Shortened growing season	 Vegetables, legumes	East Africa	High	Low	Medium	Mulch, climate advisories for timing of planting, harvesting
Absorptive	Drought, Flood, Unseasonable climate variability, Shortened growing season, High temperatures	 Maize	Southern Africa	High	Medium	Medium	Nutrient management advisories linked to weather services
Absorptive	Drought, Unseasonable climate variability, Shortened growing season	 Maize	Southern Africa	High	High	High	Changing planting dates, mechanization, no-till planting
Absorptive	Drought, Unseasonable climate variability	 Wheat	South Asia	Medium	High	High	Changing planting dates, mechanization, no-till planting
Absorptive	Unseasonable climate variability	 Rice	South Asia	High	Low	Medium	Synchronizing rice establishment to monsoon onset

Absorptive		Rice, wheat	South Asia	● (dark green)	● (light green)	● (light green)	Climate information to enable precision nutrient management
Absorptive		Rice, wheat	South Asia	● (dark green)	● (dark green)	● (light green)	Dynamic decision support for irrigation management
Transitional		Rice	West Africa	● (light green)	● (yellow)	● (dark green)	Small-scale land and water development in rainfed lowlands
Transitional		Rice, vegetable	West Africa	● (light green)	● (light green)	● (dark green)	Diversified crop rotations
Transitional		Maize	Southern Africa	● (light green)	● (yellow)	● (light green)	Intercropping, rotations, conservation tillage
Transitional		Rice	South Asia	● (light green)	● (dark green)	● (light green)	Stress tolerant varieties, relay cropping,
Transformative		Millet	West Africa	● (light green)	● (yellow)	● (light green)	Regeneration of agroforestry parklands

4. IMPLEMENTING AN ADAPTATION AGENDA

This document lays out general concepts underlying the way EiA considers agronomy and climate change adaptation. EiA will host several participatory workshops in 2023 to ensure that our strategy is tailored to regional contexts and that the broader innovation system supporting adaptation is poised for a higher level of coordinated action and co-investment. These consultations will engage stakeholders who are most familiar with ground realities and regional evidence to support the prioritization of cropping systems and entry points for climate adaptation solutions in the context of the most damaging climatic hazards. Farmers, national agriculture research organizations, policy makers, and other stakeholders will have a chance to voice their opinions at these regional gatherings. In line with our what, why, and how framework, EiA will use these convenings to segregate technology scaling priorities from those that require further R&D or risk transfer approaches . Post-workshop research and analysis with ensure that the assumptions and insights emerging from the consultations are well-grounded in evidence and that areas of uncertainty are appropriately noted. Thereafter, a second round of parnter engagment will pivot from stock-taking to planning with regionally-specific action roadmaps created. The regional events will be a crucial step in ensuring that EiA's work uses an adaptive approach to the contextual differences in climatic hazards as well as regional transferability of potential solutions.

The network of stakeholders will also be able to provide feedback on the efficiency and efficacy of EiA's programs in subsequent years. Data tracking the adaptation benefits will be essential for understanding what works for farmers and to guide subsequent programmatic changes. However, tracking adaptation differs from monitoring other common results in agronomy, such as production and soil health. The benefits depend on location, time, climate stress, and the confounding effects of social change that are often difficult to disentangle (Box 2). There are over

20 frameworks commonly used to measure resilience and adaptive capacity, but they fail to converge on methods or metrics, reducing their utility and generalization (Nowak and Rosenstock, 2020).

So far, EiA has proposed a parsimonious approach to tracking the resilience benefits of its actions, choosing to examine yield stability—a measure of variability over time or space (Kazuki et al. 2021). Addition Key Performance Indicators (KPIs) in EiA's monitoring framework are also relevant such as water use efficiency, income, and soil health, each of which can be directly measured on farms. Yet, assessing climate adaptation requires a process-based framework, aside from farm- and basin-scale KPI's, that track changes in farmer and stakeholder behavior, perceptions and capacities. (e.g., Wood et al. 2014). While EiA is tracking adaptation across space, time, and partnerships, the mechanics to cost effectively and comprehensively do so is an open and critical question for the Initiative.

Tracking adaptation is only one essential research question. While agronomy has considered biophysical resilience for years, climate change adaptation represents a new objective, raising many new questions. Based on the global strategy proposed in this document, EiA has drafted a set of starting research questions to help assess and scale agronomic solutions:

- **Impact:**
  To what extent and by which mechanisms do absorptive, transitional, or transformative actions reduce climate-induced agricultural losses and crop system damage?

- **Timescales and limits:**
  When will climate impacts emerge that limit or surpass the efficacy of agronomic solutions to improve and maintain farmer livelihoods?

- **Targeting:**
  Which agronomic options shifts are relevant for various farmers, cropping system, enabling environment, and prevailing climate hazards and how can this information be used to target and scale farm-specific solutions?

- **Prioritization:**
  How can the latest information on agronomy and climate change be best exposed to allow policymakers, private sectors, and small-scale producers to select agronomic solutions that fit their individual objectives and needs?

- **Scaling:**
  What institutional, financial, and technical barriers constrain the scaling of agronomic adaptation measures and how can they be alleviated?

- **Monitoring:**
  What monitoring frameworks, including indicators, sampling frames, and methods, can be used to assess the spatio-temporal impact of agronomic adaptation interventions in terms of crop yields, yield stability, soil health, and farmer capacities?

- **Co-benefits:**
  What is the greenhouse gas mitigation effect of large-scale agronomic adaptation?

- **Tradeoffs:**
  Does an adaptation focus compromise other farming systems' objectives or resource competition?

- **Maladaptation:**
  Can potential unintentional consequences of climate adaptation programming be predicted and mitigated within scaling processes?

These and other agronomic research questions will guide development of EiA's research for development agenda on agronomy and climate change adaptation. Better defining and amplifying agronomy's potential as a solution is crucial because agronomy directly addresses the climate risks farmers face and provides solutions relevant for practically every crop, farmer, and agro-climate conditions. Actions beyond agronomy are also needed to support adaptation, but they are outside EiA's mandate. To address climate issues in a holistic way EiA will work closely with partners with public and private sector partners, national agricultural research institutions and complementary One CGIAR Initiative such as ClimBeR, Mitigate+, Mixed Farming Systems, the regional One CGIAR initiatives to enhance scaling and uptake amongst other as well as regional scientific programs such as Accelerating the Impact of CGIAR Climate Change Research (AICCRA) to accelerate learning and influence climate action.

BOX 2. ARE AGRONOMISTS ADAPTATION-SENSITIVE?

Agronomic options clearly have climate change adaptation potential, but do agronomists account for the intended and unintended effects of agronomic interventions on a farming system's climate resiliency?

Most agronomic interventions are designed with a near-exclusive focus on current and historical crop yield. This focus would produce a reasonable estimate of future yield if the climate were unchanging or did not affect the system. However, this is rarely the case. Farming systems are inherently exposed to various climate hazards, and those hazards are shifting due to climate change. For agronomy to contribute to climate adaptation, agronomists must account for the performance of crops, farming systems, and agronomic practices under both current and future climate conditions. In practice, this largely means understanding the performance of agronomic interventions under environments at least 2°C warmer than now. Achieving this understanding requires scenario analysis, multi-site experimentation, and modeling.

Reliable quantification of agronomic climate adaptation will be crucial to its integration into decision-making as new technologies and varieties emerge regularly. Challinor et al. (2017) propose a quantitative framework to estimate adaptation effects (Figure 4A). In this framework, a non-adapted crop or farming system under the current (A1) and future (B1) climate is compared to its adapted from under the current (A2) and future (B3) climate. The effect of the agronomic intervention (B2) is also considered. Figure 4B illustrates how different systems with a similar performance at low levels of climate change, i.e., low-level warming, can respond very differently to climate change with and without a particular agronomic intervention. While this identifies valuable agronomic entry points, it lacks the social-economic context that influences farmers' decision-making, which is also influenced by climate change.

FIGURE 5

Diagram illustrating how adaptation effects of given interventions should be calculated (A) and illustrative pathways of crop or system response to warming with and without a particular agronomic intervention (B). Panel (A) is taken from Challinor et al. (2017).

ACKNOWLEDGMENTS

We thank One CGIAR's Excellence in Agronomy 2030 Initiative for their support. We thank Ani Ghosh for comments. We thank Jonas Jagermeyr for providing access to the data presented in Figure 1. Scriptoria Solutions edited an early version of this paper.

REFERENCES

Aguilera, E., Díaz-Gaona, C., García-Laureano, R., Reyes-Palomo, C., Guzmán, G.I., Ortolani, L., Sánchez-Rodríguez, M., Rodríguez-Estévez, V., 2020. Agroecology for adaptation to climate change and resource depletion in the Mediterranean region. A review. Agric. Syst. 181, 102809. https://doi.org/10.1016/j.agsy.2020.102809

Antwi-Agyei, P., Dougill, A.J., Stringer, L.C., Codjoe, S.N.A., 2018. Adaptation opportunities and maladaptive outcomes in climate vulnerability hotspots of northern Ghana. Clim. Risk Manag. 19, 83–93. https://doi.org/10.1016/j.crm.2017.11.003

Arslan, A., Floress, K., Lamanna, C., Lipper, L., Rosenstock, T.S., 2022. A meta-analysis of the adoption of agricultural technology in Sub-Saharan Africa. PLoS Sustain. Transform. 1–17. https://doi.org/10.1371/journal.pstr.0000018

Awondo, S.N., Kostandini, G., Setimela, P., Erenstein, O., 2020. Multi-Site Bundling of Drought Tolerant Maize Varieties and Index Insurance. J. Agric. Econ. 71, 239–259. https://doi.org/10.1111/1477-9552.12344

Balwinder-Singh, McDonald, A.J., Kumar, V., Poonia, S.P., Srivastava, A.K., Malik, R.K., 2019. Taking the climate risk out of transplanted and direct seeded rice: Insights from dynamic simulation in Eastern India. F. Crop. Res. 239, 92–103. https://doi.org/10.1016/j.fcr.2019.05.014

Belay, S.A., Assefa, T.T., Vara Prasad, P. V., Schmitter, P., Worqlul, A.W., Steenhuis, T.S., Reyes, M.R., Tilahun, S.A., 2020. The response of water and nutrient dynamics and of crop yield to conservation agriculture in the Ethiopian highlands. Sustain. 12. https://doi.org/10.3390/su12155989

Bertana, A., Clark, B., Benney, T.M., Quackenbush, C., 2022. Beyond maladaptation: structural barriers to successful adaptation. Environ. Sociol. 8, 448–458. https://doi.org/10.1080/23251042.2022.2068224

Blundo-Canto, G., Andrieu, N., Soule-Adam, N., Ndiaye, O., Chiputwa, B., 2020. Scaling Weather and Climate information Services for agriculture: evaluating systemic but overlooked effects. (under Rev. Clim. Serv. journal) 22, 100216. https://doi.org/10.1016/j.cliser.2021.100216

Carlson, K.M., Gerber, J.S., Mueller, N.D., Herrero, M., MacDonald, G.K., Brauman, K.A., Havlik, P., O'Connell, C.S., Johnson, J.A., Saatchi, S., West, P.C., 2016. Greenhouse gas emissions intensity of global croplands. Nat. Clim. Chang. https://doi.org/10.1038/nclimate3158

Carr, T.W., Mkuhlani, S., Segnon, A.C., Ali, Z., Zougmoré, R., Dangour, A.D., Green, R., Scheelbeek, P., 2022. Climate change impacts and adaptation strategies for crops in West Africa: A systematic review. Environ. Res. Lett. 17. https://doi.org/10.1088/1748-9326/ac61c8

Carter, S., Herold, M., Rufino, M.C., Neumann, K., Kooistra, L., Verchot, L., 2015. Mitigation of agricultural emissions in the tropics: Comparing forest land-sparing options at the national level. Biogeosciences 12, 4809–4825. https://doi.org/10.5194/bg-12-4809-2015

Chiputwa, B., Wainaina, P., Makui, P., Nakelse, T., Zougmoré, R., Ndiaye, O., 2019. Evaluating the Impact of the Multidisciplinary Working Group Model on Farmers' Use of Climate Information Services in Senegal. United States Agency Int. Dev.

Dossou-Yovo, E.R., Devkota, K.P., Akpoti, K., Danvi, A., Duku, C., Zwart, S.J., 2022. Thirty years of water management research for rice in sub-Saharan Africa: Achievement and perspectives. F. Crop. Res. 283, 108548. https://doi.org/10.1016/j.fcr.2022.108548

Eriksen, S., Schipper, E.L.F., Scoville-Simonds, M., Vincent, K., Adam, H.N., Brooks, N., Harding, B., Khatri, D., Lenaerts, L., Liverman, D., Mills-Novoa, M., Mosberg, M., Movik, S., Muok, B., Nightingale, A., Ojha, H., Sygna, L., Taylor, M., Vogel, C., West, J.J., 2021. Adaptation interventions and their effect on vulnerability in developing countries: Help, hindrance or irrelevance? World Dev. 141, 105383. https://doi.org/10.1016/j.worlddev.2020.105383

FAO, 2021. The impact of disasters and crises on agriculture and food security: 2021, The impact of disasters and crises on agriculture and food security: 2021. https://doi.org/10.4060/cb3673en

Feliciano, D., Ledo, A., Hillier, J., Nayak, D.R., 2018. Which agroforestry options give the greatest soil and above ground carbon benefits in different world regions? Agric. Ecosyst. Environ. 254, 117–129. https://doi.org/10.1016/j.agee.2017.11.032

Frelat, R., Lopez-ridaura, S., Giller, K.E., Herrero, M., Douxchamps, S., Djurfeldt, A.A., Erenstein, O., Henderson, B., Kassie, M., K, P.B., Rigolot, C., Ritzema, R.S., Rodriguez, D., van Asten, Piet, J.A., van Wijk, M.T., 2015. Drivers of household food availability in sub-Saharan Africa based on big data from small farms. PNAS. https://doi.org/10.1073/pnas.1518384112

Fuglie, K.O., 2018. Is agricultural productivity slowing? Glob. Food Sec. 17, 73–83. https://doi.org/10.1016/j.gfs.2018.05.001

Gaudin, A.C.M., Tolhurst, T.N., Ker, A.P., Janovicek, K., Tortora, C., Martin, R.C., Deen, W., 2015. Increasing crop diversity mitigates weather variations and improves yield stability. PLoS One 10, 1–20. https://doi.org/10.1371/journal.pone.0113261

Getachew, F., Bayabil, H.K., Hoogenboom, G., Teshome, F.T., Zewdu, E., 2021. Irrigation and shifting planting date as climate change adaptation strategies for sorghum. Agric. Water Manag. 255, 106988. https://doi.org/10.1016/j.agwat.2021.106988

Getnet, M., Descheemaeker, K., van Ittersum, M.K., Hengsdijk, H., 2022. Narrowing crop yield gaps in Ethiopia under current and future climate: A model-based exploration of intensification options and their trade-offs with the water balance. F. Crop. Res. 278, 108442. https://doi.org/10.1016/j.fcr.2022.108442

Gosnell, H., Gill, N., Voyer, M., 2019. Transformational adaptation on the farm: Processes of change and persistence in transitions to 'climate-smart' regenerative agriculture. Glob. Environ. Chang. 59, 101965. https://doi.org/10.1016/j.gloenvcha.2019.101965

Hansen, J., Hellin, J., Rosenstock, T., Fisher, E., Cairns, J., Stirling, C., Lamanna, C., van Etten, J., Rose, A., Campbell, B., 2018. Climate risk management and rural poverty reduction. Agric. Syst. 172, 28–46. https://doi.org/10.1016/j.agsy.2018.01.019

Herrero, M., Thornton, P.K., Power, B., Bogard, J.R., Remans, R., Fritz, S., Gerber, J.S., Nelson, G., See, L., 2017. Farming and the geography of nutrient production for human use: a transdisciplinary analysis. Lancet Planet Heal. 1, e33–e42. https://doi.org/10.1016/S2542-5196(17)30007-4

Jägermeyr, J., Müller, C., Ruane, A.C., Elliott, J., Balkovic, J., Castillo, O., Faye, B., Foster, I., Folberth, C., Franke, J.A., Fuchs, K., Guarin, J.R., Heinke, J., Hoogenboom, G., Iizumi, T., Jain, A.K., Kelly, D., Khabarov, N., Lange, S., Lin, T., Liu, W., Mialyk, O., Minoli, S., Moyer, E.J., Okada, M., Phillips, M., Porter, C., Rabin, S.S., Scheer, C., Schneider, J.M., Schyns, J.F., 2021. Climate impacts on global agriculture emerge earlier in new generation of climate and crop models. Nat. Food . https://doi.org/10.1038/s43016-021-00400-y

Jarvis, A., Rosenstock, T.S., Koo, J., Thornton, P.K., Ramirez-Villegas, J., Prager, S.D., Ghosh, A., Fuglie, K.O., 2021. Climate-informed priorities for One CGIAR Regional Integrated Initiatives. Wageningen, Netherlands.

Kates, R.W., Travis, W.R., Wilbanks, T.J., 2012. Transformational adaptation when incremental adaptations to climate change are insufficient. Proc. Natl. Acad. Sci. U. S. A. 109, 7156–7161. https://doi.org/10.1073/pnas.1115521109

Kath, J., Byrareddy, V.M., Craparo, A., Nguyen-Huy, T., Mushtaq, S., Cao, L., Bossolasco, L., 2020. Not so robust: Robusta coffee production is highly sensitive to temperature. Glob. Chang. Biol. 26, 3677–3688. https://doi.org/10.1111/gcb.15097

Kim, Dong-Gill, Kirschbaum, M., Beedy, T., n.d. Carbon sequestration and net emissions of CH4 adn N2O under agroforestry: synthesizing available data and suggestions for future studies. Agric. Ecosyst. Environ. https://doi.org/10.1017/CBO9781107415324.004

Knapp, S., van der Heijden, M.G.A., 2018a. A global meta-analysis of yield stability in organic and conservation agriculture. Nat. Commun. 9, 1–9. https://doi.org/10.1038/s41467-018-05956-1

Knapp, S., van der Heijden, M.G.A., 2018b. A global meta-analysis of yield stability in organic and conservation agriculture. Nat. Commun. 9. https://doi.org/10.1038/s41467-018-05956-1

Komarek, A.M., Thierfelder, C., Steward, P.R., 2021. Conservation agriculture improves adaptive capacity of cropping systems to climate stress in Malawi. Agric. Syst. 190, 103117. https://doi.org/10.1016/j.agsy.2021.103117

Lana, M.A., Vasconcelos, Ana Carolina F Gornott, C., Schaffert, A., Bonatti, M., Volk, J., Graef, F., Kersebaum, K.C., Sieber, S., 2018. Is dry soil planting an adaptation strategy for maize cultivation in semi-arid Tanzania? Food Secur. 10, 897–910.

Liang, K., Zhong, X., Huang, N., Lampayan, R.M., Pan, J., Tian, K., Liu, Y., 2016. Grain yield, water productivity and CH4 emission of irrigated rice in response to water management in south China. Agric. Water Manag. 163, 319–331. https://doi.org/10.1016/j.agwat.2015.10.015

Linquist, B.A., Groenigen, K.J., Adviento-Borbe, M.A., Pittelkow, C., van Kessel, C., 2012. An agronomic assessment of greenhouse gas emissions from major cereal crops. Glob. Chang. Biol. 18, 194–209. https://doi.org/10.1111/j.1365-2486.2011.02502.x

Lowder, S.K., Skoet, J., Raney, T., 2016. The Number, Size, and Distribution of Farms, Smallholder Farms, and Family Farms Worldwide. World Dev. 87, 16–29. https://doi.org/10.1016/j.worlddev.2015.10.041

Mason-D'Croz, D., Sulser, T.B., Wiebe, K., Rosegrant, M.W., Lowder, S.K., Nin-Pratt, A., Willenbockel, D., Robinson, S., Zhu, T., Cenacchi, N., Dunston, S., Robertson, R.D., 2019. Agricultural investments and hunger in Africa modeling potential contributions to SDG2 – Zero Hunger. World Dev. 116, 38–53. https://doi.org/10.1016/j.worlddev.2018.12.006

McDonald, A.J., Balwinder-Singh, Keil, A., Srivastava, A., Craufurd, P., Kishore, A., Kumar, V., Paudel, G., Singh, S., Singh, A.K., Sohane, R.K., Malik, R.K., 2022. Time management governs climate resilience and productivity in the coupled rice–wheat cropping systems of eastern India. Nat. Food 3, 542–551. https://doi.org/10.1038/s43016-022-00549-0

Mehrabi, Z., McDowell, M.J., Ricciardi, V., Levers, C., Martinez, J.D., Mehrabi, N., Wittman, H., Ramankutty, N., Jarvis, A., 2020. The global divide in data-driven farming. Nat. Sustain. https://doi.org/10.1038/s41893-020-00631-0

Mekuria, W., Gebregziabher, G., Lefore, N., 2020. Exclosures for landscape restoration in Ethiopia: business model scenarios and suitability. Colombo.

Oo, A.Z., Sudo, S., Inubushi, K., Mano, M., Yamamoto, A., Ono, K., Osawa, T., Hayashida, S., Patra, P.K., Terao, Y., Elayakumar, P., Vanitha, K., Umamageswari, C., Jothimani, P., Ravi, V., 2018. Methane and nitrous oxide emissions from conventional and modified rice cultivation systems in South India. Agric. Ecosyst. Environ. 252, 148–158. https://doi.org/10.1016/j.agee.2017.10.014

Ortiz-bobea, A., Ault, T.R., Carrillo, C.M., Chambers, R.G., Lobell, D.B., 2021. Anthropogenic climate change has slowed agricultural productivity growth. Nat. Clim. Chang. 11, 306–315. https://doi.org/10.1038/s41558-021-01000-1

Paudel, G.P., Khanal, A.R., Rahut, D.B., Krupnik, T.J., Mcdonald, A.J., 2022. Smart Precision Agriculture but Resource Constrained Farmers : Is service provision a potential solution? Farmer's willingness to pay for laser-land leveling services in Nepal. Smart Agric. Technol. 100084. https://doi.org/10.1016/j.atech.2022.100084

Pavelic, P., Magombeyi, M., Schmitter, P., Jacobs-Mata, I., 2021. Sustainable expansion of groundwater-based solar water pumping for smallholder farmers in Sub-Saharan Africa. Washiington D.C.

Pequeno, D.N.L., Hernandez-Ochoa, I.M., Reynolds, M., Sonder, K., Molero-Milan, A., Robertson, R., da Silva Sabino Lopes, M., Xiong, W., Kropff, M., Asseng, S., 2021. Climate impact and adaptation to heat and drought stress of regional and global wheat production. Environ. Res. Lett. https://doi.org/10.1016/j.snb.2007.07.003

Ray, D.K., West, P.C., Clark, M., Gerber, J.S., Prishchepov, A. V., Chatterjee, S., 2019. Climate change has likely already affected global food production. PLoS One 14, 1–18. https://doi.org/10.1371/journal.pone.0217148

Raymond, C., Suarez-Gutierrez, L., Kornhuber, K., Pascolini-Campbell, M., Sillmann, J., Waliser, D.E., 2022. Increasing spatiotemporal proximity of heat and precipitation extremes in a warming world quantified by a large model ensemble. Environ. Res. Lett. 17, 035005. https://doi.org/10.1088/1748-9326/ac5712

Renwick, L.L.R., Kimaro, A.A., Hafner, J.M., Rosenstock, T.S., Gaudin, A.C.M., Ahmed, S., 2020. Maize-Pigeonpea Intercropping Outperforms Monocultures Under Drought 4. https://doi.org/10.3389/fsufs.2020.562663

Requena Suarez, D., Rozendaal, D.M.A., De Sy, V., Phillips, O.L., Alvarez-Dávila, E., Anderson-Teixeira, K., Araujo-Murakami, A., Arroyo, L., Baker, T.R., Bongers, F., Brienen, R.J.W., Carter, S., Cook-Patton, S.C., Feldpausch, T.R., Griscom, B.W., Harris, N., Hérault, B., Honorio Coronado, E.N., Leavitt, S.M., Lewis, S.L., Marimon, B.S., Monteagudo Mendoza, A., N'dja, J.K., N'Guessan, A.E., Poorter, L., Qie, L., Rutishauser, E., Sist, P., Sonké, B., Sullivan, M.J.P., Vilanova, E., Wang, M.M.H., Martius, C., Herold, M., 2019. Estimating aboveground net biomass change for tropical and subtropical forests: refinement of IPCC default rates using forest plot data. Glob. Chang. Biol. 0–3. https://doi.org/10.1111/gcb.14767

Ricciardi, V., Ramankutty, N., Mehrabi, Z., Jarvis, L., Chookolingo, B., 2018. How much of the world's food do smallholders produce? Glob. Food Sec. 17, 64–72. https://doi.org/10.1016/j.gfs.2018.05.002

Rippke, U., Ramirez-Villegas, J., Jarvis, A., Vermeulen, S.J., Parker, L., Mer, F., Diekkrüger, B., Challinor, A.J., Howden, M., 2016. Timescales of transformational climate change adaptation in sub-Saharan African agriculture. Nat. Clim. Chang. 6, 605–609. https://doi.org/10.1038/nclimate2947

Rosenstock, T.S., Lamanna, C., Chesterman, S., Bell, P., Arslan, A., Richards, M., Rioux, J., Akinleye, A.O., Champalle, C., Cheng, Z., Corner-dolloff, C., Dohn, J., English, W., Eyrich, A., Girvetz, E.H., Kerr, A., Lizarazo, M., Madalinska, A., Mcfatridge, S., Morris, K.S., Namoi, N., Poultouchidou, A., Ravina, M., Richards, M., Akinleye, A.O., Corner-dolloff, C., English, W., Eyrich, A., Girvetz, E.H., Kerr, A., Lizarazo, M., Madalinska, A., McFatridge, S., Morris, K.S., Namoi, N., Poultouchidou, A., Ravina da Silva, M., Rayess, S., Strom, H., Tully, K.L., Zhou, W., 2015. The scientific basis of climate-smart agriculture: A systematic review protocol (No. 38). Nairobi, Kenya.

Samberg, L.H., Gerber, J.S., Ramankutty, N., Herrero, M., West, P.C., 2016. Subnational distribution of average farm size and smallholder contributions to global food production. Environ. Res. Lett. 11. https://doi.org/10.1088/1748-9326/11/12/124010

Sida, T.S., Baudron, F., Kim, H., Giller, K.E., 2018. Climate-smart agroforestry: Faidherbia albida trees buffer wheat against climatic extremes in the Central Rift Valley of Ethiopia. Agric. For. Meteorol. 248, 339–347. https://doi.org/10.1016/j.agrformet.2017.10.013

Smit, B., Skinner, M.W., 2002. Adaptation options in agriculture to climate change: A typology. Mitig. Adapt. Strateg. Glob. Chang. 7, 85–114. https://doi.org/10.1023/A:1015862228270

Smith, P., Calvin, K., Nkem, J., Campbell, D., Cherubini, F., Grassi, G., Korotkov, V., Le Hoang, A., Lwasa, S., McElwee, P., Nkonya, E., Saigusa, N., Soussana, J.F., Taboada, M.A., Manning, F.C., Nampanzira, D., Arias-Navarro, C., Vizzarri, M., House, J., Roe, S., Cowie, A., Rounsevell, M., Arneth, A., 2020. Which practices co-deliver food security, climate change mitigation and adaptation, and combat land degradation and desertification? Glob. Chang. Biol. 26, 1532–1575. https://doi.org/10.1111/gcb.14878

Snapp, S.S., Blackie, M.J., Gilbert, R.A., Bezner-Kerr, R., Kanyama-Phiri, G.Y., 2010. Biodiversity can support a greener revolution in Africa. Proc. Natl. Acad. Sci. U. S. A. 107, 20840–20845. https://doi.org/10.1073/pnas.1007199107

Springmann, M., Mason-D'Croz, D., Robinson, S., Garnett, T., Godfray, H.C.J., Gollin, D., Rayner, M., Ballon, P., Scarborough, P., 2016. Global and regional health effects of future food production under climate change: A modelling study. Lancet 387, 1937–1946. https://doi.org/10.1016/S0140-6736(15)01156-3

Stevenson, J., Vanlauwe, B., Macours, K., Johnson, N., Krishnan, L., Place, F., Spielman, D., Hughes, K., Vlek, P., 2019. Farmer adoption of plot- and farm-level natural resource management practices: Between rhetoric and reality. Glob. Food Sec. 20, 101–104. https://doi.org/10.1016/j.gfs.2019.01.003

Steward, P.R., Thierfelder, C., Dougill, A.J., Ligowe, I., 2018. Conservation agriculture enhances resistance of maize to climate stress in a Malawian medium-term trial. Agric. Ecosyst. Environ. https://doi.org/10.1016/j.agee.2018.07.009

Tesfaye, K., Takele, R., Sapkota, T.B., Khatri-Chhetri, A., Solomon, D., Stirling, C., Albanito, F., 2021. Model comparison and quantification of nitrous oxide emission and mitigation potential from maize and wheat fields at a global scale. Sci. Total Environ. 782, 146696. https://doi.org/10.1016/j.scitotenv.2021.146696

Thorlakson, T., Neufeldt, H., 2012. Reducing subsistence farmers' vulnerability to climate change: evaluating the potential contributions of agroforestry in western Kenya. Agric. Food Secur. 1, 15. https://doi.org/10.1186/2048-7010-1-15

van Dijk, M., Morley, T., Rau, M.L., Saghai, Y., 2021. A meta-analysis of projected global food demand and population at risk of hunger for the period 2010–2050. Nat. Food 2, 494–501. https://doi.org/10.1038/s43016-021-00322-9

van Oort, P.A.J., Zwart, S.J., 2018. Impacts of climate change on rice production in Africa and causes of simulated yield changes. Glob. Chang. Biol. 24, 1029–1045. https://doi.org/10.1111/gcb.13967

Vermeulen, S.J., Challinor, A.J., Thornton, P.K., Campbell, B.M., Eriyagama, N., Vervoort, J.M., Kinyangi, J., Jarvis, A., Laderach, P., Ramirez-Villegas, J., Nicklin, K.J., Hawkins, E., Smith, D.R., 2013. Addressing uncertainty in adaptation planning for agriculture. Proc. Natl. Acad. Sci. U. S. A. 110, 8357–8362. https://doi.org/10.1073/pnas.1219441110

Vermeulen, S.J., Dinesh, D., Howden, S.M., Cramer, L., Thornton, P.K., 2018. Transformation in practice: A review of empirical cases of transformational adaptation in agriculture under climate change. Front. Sustain. Food Syst. 2. https://doi.org/10.3389/fsufs.2018.00065

Vicedo-Cabrera, A.M., Scovronick, N., Sera, F., Royé, D., Schneider, R., Tobias, A., Astrom, C., Guo, Y., Honda, Y., Hondula, D.M., Abrutzky, R., Tong, S., Coelho, M. de S.Z.S., Saldiva, P.H.N., Lavigne, E., Correa, P.M., Ortega, N.V., Kan, H., Osorio, S., Kyselý, J., Urban, A., Orru, H., Indermitte, E., Jaakkola, J.J.K., Ryti, N., Pascal, M., Schneider, A., Katsouyanni, K., Samoli, E., Mayvaneh, F., Entezari, A., Goodman, P., Zeka, A., Michelozzi, P., De'Donato, F., Hashizume, M., Alahmad, B., Diaz, M.H., Valencia, C.D.L.C., Overcenco, A., Houthuijs, D., Ameling, C., Rao, S., Di Ruscio, F., Carrasco-Escobar, G., Seposo, X., Silva, S., Madureira, J., Holobaca, I.H., Fratianni, S., Acquaotta, F., Kim, H., Lee, W., Iniguez, C., Forsberg, B., Ragettli, M.S., Guo, Y.L.L., Chen, B.Y., Li, S., Armstrong, B., Aleman, A., Zanobetti, A., Schwartz, J., Dang, T.N., Dung, D. V., Gillett, N., Haines, A., Mengel, M., Huber, V., Gasparrini, A., 2021. The burden of heat-related mortality attributable to recent human-induced climate change. Nat. Clim. Chang. 11, 492–500. https://doi.org/10.1038/s41558-021-01058-x

Waha, K., Dietrich, J.P., Portmann, F.T., Siebert, S., Thornton, P.K., Bondeau, A., Herrero, M., 2020. Multiple cropping systems of the world and the potential for increasing cropping intensity. Glob. Environ. Chang. 64, 102131. https://doi.org/10.1016/j.gloenvcha.2020.102131

Wheeler, T., von Braun, J., 2013. Climate change impacts on global food security. Science (80-.). 341, 508–13. https://doi.org/10.1126/science.1239402

Wiebe, K., Lotze-Campen, H., Sands, R., Tabeau, A., Van Der Mensbrugghe, D., Biewald, A., Bodirsky, B., Islam, S., Kavallari, A., Mason-D'Croz, D., Müller, C., Popp, A., Robertson, R., Robinson, S., Van Meijl, H., Willenbockel, D., 2015. Climate change impacts on agriculture in 2050 under a range of plausible socioeconomic and emissions scenarios. Environ. Res. Lett. 10. https://doi.org/10.1088/1748-9326/10/8/085010

Xu, X., Sharma, P., Shu, S., Lin, T., Ciais, P., Tubiello, F.N., Smith, P., Campbell, N., Jain, A.K., 2021. Global greenhouse gas emissions from animal-based foods are twice those of plant-based foods. Nat. Food. https://doi.org/10.1038/s43016-021-00358-x

Yang, H., Dobbie, S., Ramirez-Villegas, J., Chen, B., Qiu, S., Ghosh, S., Challinor, A., 2020. South India projected to be susceptible to high future groundnut failure rates for future climate change and geo-engineered scenarios. Sci. Total Environ. 747, 141240. https://doi.org/10.1016/j.scitotenv.2020.141240

SUPPLEMENTARY NOTE 1: GLOSSARY

KEY CONCEPTS AND TERMS ON CLIMATE CHANGE ADAPTATION AND AGRONOMY.

Accompanying measure(s).	Requisite factors that must be in place for farmers to use agronomic solutions. These may include access to finance, tenure, soil labs, and service providers. May present additional entry points to stimulate the uptake of agronomic solutions.
Adaptability.	The capacity of smallholder farmers and other food systems actors to impact resilience.
Adaptation.	Actions that reduce the vulnerability of farmers and farming systems to climate change. May be proactive or retroactive and require minor to radical behavior change.
Adaptive capacity.	Skills and capacities such as knowledge, finance, and technical capacity that permit farmers or institutions to adjust behavior that mitigates the impact of climate hazards or capture opportunities.
Adaptation pathways.	A series of events or decision points over time that adjust behavior, typically variable to constraints and livelihood trajectories of heterogenous farmer and farming system.
Agronomy.	The integrated management of crops, nutrients, water, soil, and pests and diseases.
Business model.	Enterprises' way of working that creates value, usually financial, but more recently expanded to societal value, including building smallholder farmer resilience.
Exposure.	The degree a system is subject to a climate hazard.
Hazard.	A climate event or process that can harm farmers or farming systems. These can be slow onset such as changing mean temperatures or sudden extreme event like a flood.
Impact.	Hazards' effect on farming systems and farmers, such as a loss in productivity; a function of exposure and sensitivity.
Impact pathway.	The series of steps outlining the events, beliefs, and accompanying measures for how adaptation action change outcomes
Incremental adaptation.	Minor progressive behaviour changes to minimize loss or increase resilience of an existing system.
Maladaptation.	An adaptation action that unintentionally increases the ecological or social system vulnerability.
Minimum viable product (MVP).	Prototype of a product with sufficient detail/features to draw interest and begin to catalyse a user base.
Resilience.	The ability for ecological or social systems to cope with and recover from stress and shocks.
Risk.	The combination of exposure and vulnerability to hazards; potential for adverse consequences.
Robustness.	Capacity to withstand climate stress and maintain function.
Sensitivity.	The negative or positive extent of impact a climate hazard has on ecological or human systems.
Shared socioeconomic pathways (SSP).	Signify plausible future climate scenarios as determined by rate of greenhouse gas emissions, with SSP126 and SSP585 representing the low emissions and high emissions, and thus the low and high ends of plausible future scenarios.
Systematic adaptation.	Significant changes in system management to maintain functionality, such as shifting production across altitudinal gradients.
Transformative adaptation.	Drastic changes in farmer livelihoods' and farming systems' design and function, such as leaving farming altogether or switching crops, usually because farming has already become untenable or will become so.
Transformability.	The capacity to transition to a new production or livelihood system in response to social, economic, or ecological stress weakening or wreaking existing system.
Vulnerability.	The level to which a system is subject to and has negative effects from climate change variability and extremes.

ANNEX 2

CONVENING AGENDA

DAY 1

<table>
<tr><th>Time</th><th>Session blocks and description</th><th>Who responsible</th></tr>
<tr><td>8:00</td><td>Registration</td><td>Aaron Lumpkin</td></tr>
<tr><td colspan="3">Introductions</td></tr>
<tr><td>8:45</td><td>Welcomes</td><td>Christian Witt (BMGF)</td></tr>
<tr><td></td><td>Objectives of the meeting and setting the scene</td><td>Bernard Vanlauwe (EiA)</td></tr>
<tr><td></td><td>Agenda- Flow</td><td>Tonya Schuetz (ABC)</td></tr>
<tr><td></td><td>Participants</td><td>T. Schuetz (ABC)</td></tr>
<tr><td>10:30</td><td>Coffee</td><td></td></tr>
<tr><td colspan="3">Part 1: Challenging EiA’s climate logic
Relevance of the global framework and strategy doc and its adaptiveness to implementation in the different regions pending variations in perceived climate hazards and shocks requiring different sets of agronomic practices and solutions.

Objective 1: collect the wide ranged different views on agronomic entry points for climate adaptation – and implications for mitigation.
Expected output from this session: a sufficiently long list of agronomic entry points identified.</td></tr>
<tr><td>11:00</td><td>Pushing the limits moving beyond silver bullets…</td><td>Julian Ramirez (ABC), Dominque Klauser (Syngenta)</td></tr>
<tr><td></td><td>Challenging EiA’s climate logic
Identifying agronomy-related climate adaptation options which enhance farmer’s absorptive, adaptive, or transformational capacity in the respective regions</td><td>All participants</td></tr>
<tr><td></td><td>Present what groups came up with</td><td>T Schutz, all participants</td></tr>
<tr><td>12:45</td><td>Lunch</td><td></td></tr>
<tr><td colspan="3">Part 1: Challenging EiA’s climate logic
Relevance of the global framework and strategy doc and its adaptiveness to implementation in the different regions pending variations in perceived climate hazards and shocks requiring different sets of agronomic practices and solutions.

Objective 2: Identify by region what are the most promising entry points.

Expected output from this session: Most likely agronomic entry points per region and list of rationale why</td></tr>
</table>

13:45	Considerations for adaptation prioritization	Brendan Brown, CSIRO
	Prioritization exercise for climate adaptation options in the regions	All Participants
15:00	Coffee	
15:30	Each region presenting their prioritization and rationalization for why	All Participants
16:00	Plenary discussion on prioritization	Tonja Schutz
16:30	Summary observations on EiA's climate logic so far - Compelling opportunities in the adaptation space - What are we missing?	
17:10	Adjourn	
17:30	Get together	

DAY 2

Time	Session blocks and description	Who responsible
8:15	Check-in for Day 1 report back on the summary observations	TBC
Part 2 - Operationalization of EiA's Climate logic: Tools and partners **Tools and approaches to monitor the impact** of implemented climate adaptive/ mitigative options on agricultural productivity, livelihoods, environment, gender and social inclusion across time and spatial scales **AND** **Necessary partnerships** to ensure farmers have access, can adapt and enhance climatic resilience at scale **Objective 2a** : narrow down to some practical most suitable tools and approaches to monitor impact **Objective 2b** :identified key partners to prioritize and to deliver adaptive agronomic solutions in the region? **Expected output from this session**: a) Identified most suitable KPIs, tools and sampling methods to assess spatio-temporal impact of climate adaptation measures b) Identified key partnerships for prioritization and delivery of adaptive agronomic solutions in the region?		
9:00	Rooting for Climate Adaptation	Hard Talk Todd Rozenstock (ABC) and Sophie Rottmann, Shamba Shape Up
9:10	Topic 1a Identify most suitable KPIs, tools and sampling methods to assess spatio-temporal impact of climate adaptation measures	All participants
	Topic 1b Identify key partnerships and scaling activities to bring the identified 3-5 entry points for climate adaptation to scale	All participants
	Report back 1 a and 1 b (15' each)	
10:30	*Coffee*	
Part 3 – Strengthening EiA's Climate logic **What are crucial gaps, disruptive tools and technologies and moonshot ideas to advance the climate adaptation agenda** **Objective 1**: Collect crucial knowledge gaps to identify, design, implement climate adaptation options, bringing these to scale, and monitor impact. **Expected output from this session**: Suggestions of gaps that needs addressing to advance the climate adaptation agenda		
11:00	Identify knowledge gaps, disruptive technologies and moonshot ideas	T Schutz, all participants
	Feedback of groups into plenary	Small groups
12:30	*Lunch*	

ANNEX 3

CONVENING SLIDE DECK

Please access the full slides here SLIDES

ANNEX 4

THE CAPTAIN (THE CLIMATE ADAPTATION PRIORITIZATION TOOL)

EiA team is building the CAPTain (The Climate **A**daptation **P**rioritization **T**ool) framework to facilitate a stakeholder-led process to collaboratively learn and collectively prioritize agronomic adaptation options that respond to the most pressing contemporary and projected climate hazards while identifying knowledge gaps and key areas of uncertainty. The tool combines quantitative data with expert elicitation through discussion-based consultations to characterize and explore potential adaptation solutions for specific crop production regions. It is also envisioned that the CAPTain will emerge as 'living' framework that facilitates learning and re-prioritization as new evidence and agronomic innovations emerge. The purpose of the prioritization sessions during the convening was to explore the prioritization logic EiA has been developing and discussed with participants the indicators used in the stakeholder-led process.

A sequential process has been defined to develop, deploy, and subsequently leverage the result of the prioritization exercise in a synthesis and design phase. Within the next 18 month, EiA will take the following steps:

1 **Set the stage:**
In consultation with national (and regional) partners, define the boundaries of key crop production ecologies that will serve as the basis for adaptation assessments completed in 2023. Partner institutions will be enlisted as co-convenors of process and technical working groups will be composed to provide data, identify workshop participants, and validate workshop insights with a broader group of stakeholders.

2 **Assemble data and evidence:**
Aggregates insights on the main regional agro-climatic hazards, the anticipated impacts on different crops, and the advantages of different adaptation options. Whenever possible, this step will capitalize on existing knowledge and synthesis work for scene-setting and populating basic data on crops, area cultivated, yield, and economic value.

2 **Co-convene participatory workshops:**
With the CAPTain framework, produces an initial set of adaptation priorities for R&D, scaling, and risk transfer approaches through multi-criteria assessment. Workshops do not provide definitive guidance, but rather 'socializes' the logic of priority setting, ground conversations in data and critical reflection, and works towards consensus while identifying areas of uncertainty.

4 **Validate workshop findings:**
Conducts a systematic review of workshop results from a broader group of stakeholders while addressing areas of uncertainty. Also considers the 'weights' given to different evaluation criteria and identifies potential process 'blind spots' (e.g., opportunities for transformative change).

5 **Leverage results:**
Develops action roadmaps to guide and coordinate investment (second business cycle of EiA, influence on national adaptation plans, etc.). Recurrent tool updating to learn and evolve approach.

6 **Synthesize:**
Global and regional lessons learnt and summarized in the form of journal articles for wide visibility and influence. Additional communications products showcase key results to non-academic audiences.

FEEDBACK ON THE CURRENT INDICATORS:

- **Benefits:**
  While productivity is important, it may be better to focus on profitability and risk associated with the adoption of the solution. The benefits might be larger for some actors in the value chain than for the farmer. Co-benefits related to nutritional gains, environmental impacts, and cultural preferences should be considered.

- **Evidence:**
  Capturing evidence for a bundle of options is complex, and different farm sizes/farmer segments may have varying levels of evidence available. The time frame for evidence needs to be specified, and modeling results for long-term impacts may have high uncertainty.

- **Community:**
  The evaluation should consider the farmer's current knowledge and innovation capacity, access to extension information, cultural/local preferences, and current adoption levels.

- **Government:**
  The evaluation should include current support for the technologies in policies, enabling or disabling policies, and the availability of subsidies/incentives for the technology. These indicators may reflect the "push" for technology rather than demand.

- **Private sector:**
  The evaluation should consider financing institutions, whether private sector companies are asking for the solution and if it fits their business model, whether the private sector is already involved, and what barriers exist for the private sector to be involved/scale/invest.

- **Ease:**
  This criterion needs to be unpacked into access, use, complementarity to existing systems, market value chains, access to credit, finance, insurance, and other factors.

- **Implications:**
  Environmental trade-offs and co-benefits should be considered, along with labor demand or shortage, and food and nutrition security.

- **Inclusion:**
  Gendered preferences for crops, impact on nutrition, control over income, and youth involvement should be considered. The evaluation should also link farmer diversity to potential unequal benefits generated from the innovation and whether it could potentially widen the inequality gap.

The team also noted that criteria related to health were missing in the assessment, as some of the solutions might increase health risks related to agrochemical application, waterborne diseases, etc.

ANNEX 5

SUMMARY OF INFORMATION COLLECTED IN THE BREAKOUT SESSIONS

SUMMARY FROM FLIP CHARTS

ESA – FLIP CHARTS

SI II.CA (Tradeoff)
What are the tradeoffs between SI and CA Across scales.
Does an adaptation lens compromise the other objectives

Limits

- When are the tipping points
- What are the spatial/temporal points
- Risk reduction/risk transfer – when is the transition
- How to decide when agronomy is not enough
- Can land suitability map and agroclimatic be updated more frequently to match changes in variability?
- What type of agronomic practices can help minimize soil degradation e.g., soil c, erosive events
- What is possible given other demands on the materials
- How best to get to the research questions and innovations
- How to deliver consistent information to various stakeholders
- What is the economic value of climate predictions
- What type of analytics needed for near term approaches to better inform
- How can AI be used to responsibly influence farmer behavior

DATA COLLECTION

- Exposing the data to other audiences
- Cultural change value of data
- Constellation of weather satellites, 45mm latency, 4km resolution. Reduction in cost – forecast models
- R.S disruptive – think outside of survey box, but link to survey
- Data DPS
- Farmer data collection. But how?

RESEARCH

- Paradigm shift in PhD process. Find different ways of influencing behavioral change ramification
- Chat GPT hybrid approach/Rothamstead
- Sensors/TOT
- Conceptual understanding of climate predictions futility in agronomy split

SCALING DELIVERY

- TommorrowNow – non-profit to leverage private investments
- Next generation weather data information
- Influence behavior change – gamification
- Chat GPT
- Take better advantage of climate prediction

DATA MANAGEMENT COLLECTION

- Looking at other fields – biomedical sciences, early warnings FS. Can Ethiopia support expansion and extension

DELIVERY/RESEARCH

- Climate adaptation tracking – think differently
- Why is adoption so low
- Peer to peer exchange
- Green fertilizer/biochar
- Data security, ownership and privacy – wallet, take analytics to the data. Model on synthetic data and then apply
- Disrupt in partnership side – understanding of climate inputs
- Integration of data services
- Learn from farmers how they manage risk
- Data will unlock innovation itself

ASIA FLIPCHARTS

Technical options

HAZARDS

- Drought
- Flood
- Unseasonal climate variability
- Shortened growing season
- High temperatures
- Salinity
- Cold stress
- Cyclone/extreme weather events

PARTNERSHIP

- What partnerships/stakeholders in the region needed to prioritize adaptive agronomy solution (technical working group)
- To deliver/scale solutions

WORKFLOW

- Identify priority geographies
- Key stakeholders in the priority geographies and international experts
- Assembly of evidence (hazards and agronomy options)
- Workshop using CAPTAIN
- Validation of workshop outputs
- Road mapping/implementation plan
- Synthesis paper

STAKEHOLDERS EIGP NATIONAL LEVEL

- CRIDA
- ICAR
- ATARI

STATE LEVEL

- BHU
- RPCAU
- BAU
- State Department of Agriculture

PRIVATE SECTOR

- Jeevika
- BISA
- Bayer
- PXD++
- World Bank
- NABARD

KISAN CALL CENTRE

Google sheet (shared) to populate list

BANGLADESH

- BARC (Co-convene)
- BARI
- BRRI
- BMDA
- Ministry of Environment and Climate Change
- Khulna
- ICCCAD
- Private sector – multiple
- Solidaridad
- USAID Partners
- FAO
- DAE
- WB

NEPAL

- Ministry of forest and environment
- Ministry of agriculture and Livestock
- NARC (co-convener)
- Agricultural Forestry Union
- Tribhuvan University
- FAO
- ECIMOD
- PMAMP
- USAID – FTF
- Kisan-Z

- GWRDP
- DWRI
- DHM
- National Farmer Association/Water User Association
- Provincial Government (Dept of Agriculture)
- Local Government body
- Local farmer and water user group
- FWU
- Agrovets

PRIORITY GEOGRAPHY FOR ADOPTION

INDIA

- IGP – EIGP and WIGP

BANGLADESH

- Southern Bangladesh
- Barind tract

NEPAL

- Western terrain
- Climate Shocks
- Practice (evidence…. they are adaptive)
- Yield stability
- Is climate information useful to make a crop
- Factors associated with change.
- How to measure impact
    - 10 years impact data
- EiA should monitor change in its practice
- Mix with model (Ex-Ante for model impact)
- Multi/occasional trials
- Need evidence once adopted
- Separate measuring indicators/measuring impacts
- Need to clearly define adaptations
- Preventative, Curative/Define other objectives… adaptation/resilience
- Re-indicators--- use in other sciences
- Economics
- Nutrition/Health (Medicine)

AGRONOMY IS A MEDICINE FOR A SICK AGRICULTURE/PLANET

- Combined with transform
- What Scale??
    - Field- Farm- Community
- Methods/Tools/Sytems
    - Use of EO...? Opportunities practices (i.e., residues)
    - What's grow/timing of operations extreme events…..
- TRADE OFFS IN TERMS OF COSTS/SAMPLING INTELLIGENCE WAYS
- Multi-dimensional
- Counterfactual------Causal Analysis
- What is the process and whether it is leading towards adaptations
- What is the purpose of strategy
    - How Robust are the adaptations
- Focus on adaptations
- Risk of Impact on adaptation
    - Need to think about impact on general trend on development
- TFP
- TRADE OFF RISK BY USE CASES OF MEASURING ADAPTATIONS/DISADAPTATION.

WCA – FLIP CHARTS

Top three suggested solutions

- Crop system – maize
- LOC – SAHEL
- Hazard – drought, shift in planting season, heat stress
- Bundle – rainwater harvest, climate resilient variety, integrated soil fertility management and organic matter
- Weather forecast
- Crop diversification

AGRO FORESTRY

- Crop system – rice
- Hazard – floods
- Bundle – farming shifts rice
- Climate services
- Small reservoirs

CLIMATE HAZARDS

- Increased incidents of drought
- Increased floods
- Pests and diseases
- Sea level rise – salinization, coastal erosion
- Invasive species
- Different effects plus compounding effects across space, time and crops
- Understand re-occurrence/patterns
- Shifts in re-occurrence/patterns
- Degradation of soil fertility and natural resources

DELIVERY AND ADVISORY SERVICES

- Nestle – soybean, general agronomy and climate smart agronomic targets
- ESOKO
- AFAAS – extension advisory services, country-based groups strong in the countries
- Enablers – OCP, FMAN, Sterling Bank/Master Card Foundation, Smart Nkunganire, Ghana agricultural insurance pool
- BOA
- NIRSAL

KNOWLEDGE GENERATION

- NARS for each country
- University faculties and research canters
- CGIAR scientists
- WACWISA
- West African Centre for Crop Improvement
- Centre for dryland agriculture
- Food for West Africa Network

DAY 2

- Climate forecasts
- Development and delivery of agro-advisories
- Enablers – insurance, inputs, mechanization

CLIMATE

- Nigeria Met
- Ghana Met
- Agryhymet
- NASCAL
- FeusNet
- Ignitia
- NASRDA

GOVERNMENT

- Active support of the technology
- Enabling policies
- Subsidies/Incentives
- Private sector (Financial institutions)
- Are the private sector actively looking for the solutions
- Is private sector already involved
- Are they ready to invest

EASE

- Unpack – access, use, complementarity to existing systems, markets value chains, policy, credit finance and insurance
- Where does land tenure sit
- Implications
- Environment trade offs
- Co benefits
- Carbon demand?
- Nutrition
- Food security

INCLUSION

- Gender preference for crops
- Co nutrition
- Discontinued income
- Youth involvement
- Farmer diversity
- Wider inequality

HEALTH

- Malaria
- Water related pests and diseases
- Application of agro-chemicals

MISSING CRITERIA

- Benefits – climate resilience are unequal – who benefits
- Productivity
- Profitability

EVIDENCE

- Complex evidence on individual components when in a bundle
- Farm systems/different levels of evidence
- Time new & future
- Uncertainty of modelling
- Farmer knowledge and innovation capacity
- Access to extension information
- Cultural and local preferences
- Champions/adoption levels

CLIMATE CHANGE RESEARCH QUESTIONS

1. What methods are available to link hazards to specific agronomic solutions after different levels of stress
2. Can systems be made that provide account for various levels
3. Is agronomy effective for high stress systems
4. How to socialize the potential for maladaptation
5. To what extent does perceive risk water in security at household level impact adoption of agronomic practices for climate adaptation
6. How do we enhance agility in agronomic climate solutions
7. What mechanisms can be used to stimulate bundling of agronomic solutions at the farm gate – win-win partnerships
8. What are the adoption limits – crop, farming capacity, natural resources, climate change
9. How to integrate adaptation with mainstream development
10. How to make optimum use of the concept of 'homologues'. Requires a proper data effort.
11. How to deliver consistent info on climate change+adaptation across different levels (region, country, adm, unit, farmers)
12. How do these interventions impact different groups plus with what consequence (esp. focus on gender plus also pro-poo, less)
13. Focus on tradeoffs is a more cross cutting/ overarching way? (Adaptation, mitigation, production, intensification)
14. EiA = Sustainable intensification + climate adaptation. What does sustainable intensification look like in this space?
15. Can agroclimatic zoning be made more dynamic accounting for climate change
16. How will climate change affect soil conservation
17. Does better latency and spatial resolution in weather and climate data make a difference in terms of farmer use benefits?
18. What are the tradeoffs between sustainable intensification and climate adaptation across timescales
19. What is the economic value of climate prediction at different timescales for agronomic decision making
20. How to approach transformational adaptation given high uncertainty in climate risk market plus other conditions related to timescales. When do you support/propose transformation?
21. Tradeoff: does an adaptation focus compromise other farming system objections?
22. What is the place of risk management (beyond agronomy) in supporting successful adoption plus scaling. How to know the right risk reduction level.
23. How can I be responsibly used to influence farmer behavior
24. How can data ownership/management enhance the uptake of advisory services

MOONSHOT IDEAS

- Linking/connectivity – farm systems and landscape – support resilience and adaptation
- Gaps crop modelling for specific crops and knowledge gaps
- GCF powered super sustainable integrated farming practices – make the finance flow for farmers – carbon credits
- 1000000 Tech savvy professionals to drive extension/advisory services by 2025
- CGIAR/EiA obsolete by 2050
- Ag in the center
- Global acceleration for agronomy adoption active in the 6 regions to facilitate scaling to reach 10 mil farmers
- Rethinking farming
- Growing vertically – nutrient, water, environment
- Accelerate mechanization net zero – 10 million households
- EiA generates 1 billion USD from carbon credits for farmers
- Happy and healthy farmers
- Energy sector finances – ecosystem services
- Linking carbon waste to soil
- Agronomy is used to identify alternative non-farm livelihood options
- Crop replacement/diversification to increase farm income by 30%
- Thresholds for land sizes – where climatic adaptation makes economic sense
- Radical shifts – investigate the hard questions – has agronomy on note for climate adaptation, vertical farming, peri-urban and food waste
- Are we doing the right thing?
- 25% of farmers in degraded very climate untenable locations grow into oceans insects/seaweed instead of crops

SUMMARY HARVEST OF END OF DAY 1 DISCUSSION

CHRISTIAN WITT

- How would you aggregate key themes emerging from regional consultations to a global EiA research agenda
- Would there be value in leading the regional prioritization with data and analytics

KENNETH MUBEA
IMPLEMENTER PERSPECTIVE

- Stakeholder mapping – multistakeholder
- Collaboration/partnership strategic
- Local impact
- Local knowledge/validation – space to village
- Keep partners and stakeholders engaged

EAST AFRICA RESEARCHERS GROUP

- What was striking – despite so many climate information systems out there, it was clear that there is still a big gap in accessibility of such systems for small holder farmers
- Collins Marita

FROM A RESEARCHER/OVERALL PERSPECTIVE

- More understanding and detail on carbon credits
- Aspects of affordability at the farmer level

DOMINIK KLAUSER

- We seem too able to be more precise in predicting climate and crop modelling. How can we be better at using this data?

JIBRIN

- What are the opportunities for new research – are the current technologies going to be relevant under future climate scenarios? Most of the models look at crop performance with respect to changing temperature and rainfall pattern without looking at how changing climate affects pests and diseases which in turn affect the crops.

CHRISTIAN THIERFELDER
FROM A RESEARCH PERSPECTIVE

- Focus too much on adaptation. What about mitigation benefits

JOB KIHARA

- Benefits of adaptive agronomy in future perspective especially where models are not well developed
- Field/Plot and linkages to the landscape. Co-location or linkages of EiA with interventions at landscape scale has greater success.

TODD ROSENSTOCK

- Need compelling ideas
- Lots of agronomic opportunities
- There is real opportunity in bringing this together

PRACTITIONER

- Opportunities exist for collaboration. This will be critical in operationalizing advisories emerging from EiA.
- It would be good to have a dedicated WP/Work stream to this effect
- Regional planning will still require a 'country-based approach'. Context matters
- Even agronomy thought pieces can benefit from non-agronomist disciplines contribution. Ideas, constructive critique. We must avoid 'group think' and challenge our assumptions

VINOD KUMAR SINGH

- Moisture management through best agronomic practices can bring maximum adaptation and mitigation to address climate change.

CHRISTIAN THIERFELDER

- Clearing house, who decides what is more important than the other

MARTIN VAN ITTERSUM
FROM AN OBSERVER'S PERSPECTIVe

- Mainstream climate change with integration/yield increase in SSA (until 2050 may not be the main challenge)
- Making use of homologues to identify and evaluate adaptation measures

NICK SITKO

- Thinking about bringing effective agronomic practices to scale will require multisectoral approaches. One promising option is linking the promotion of this practice with the national social protection system. This is happening in a few places and evidence shows strong benefit for inclusive adaptation. Helps manage costs and risks and shifts farmers horizons
- Need to think of adaptation as a behavior change and draw on behavioral science insights for adoption.

HEIDI WEBBER
FROM THE OBSERVER'S PERSPECTIVE

- Make use of GCF as money to offset climate risks to incentivize sustainable agronomy (entries social protection or insurance).
- Climate homologues

Differentiation of climate risks (limits adoption of agronomy) and this will get worse in CC from adaptation. My worry is that too strong of a focus on risk reduction may lock farmers into poverty plus risk reduction. Instead of prudent risk taking to make systems more sustainable.

MORUP

FROM AN IMPLEMENTOR PERSPECTIVE

- Opportunity to propel agribusiness towards data driven farming at large encompassing social, economic and climate factors such as nutrition. This can be a huge opportunity to help expedite the transition from traditional practice (ancestral intelligence) to data driven practice (artificial intelligence).
- I believe tools existing does not really help the last mile farmer. How can we guide the partners to create on such platform?

TESFAYE SIDA
FROM A RESEARCHER PERSPECTIVE

- Lack of mapping existing adaptation practices.
- There is no clear scaling strategy outlined

MARCELO GALDOS
FROM AN OBSERVER PERSPECTIVE

- Given dynamic systems with high spatial and temporal variability, there is a need for agile adaptation

JAMES ALDEN
FROM AN IMPLEMENTOR PERSPECTIVE

- A collaboration ecosystem between public and private sector research plus innovation to stop duplicating work and create new opportunities

OBSERVER GROUP

- Context of the report
- RUES link
- Education and training
- Lead farmer

MOVING FROM PLOT/FARM TO LANDSCAPE

- Water harvesting
- Flood management
- Nutrient recycling
- Credits

MANDLENKOSI NKOMO
FROM AN IMPLEMENTOR'S PERSPECTIVE

- Collaborative digital platforms for general content. (Promote/support incentives)
- Building tools that farmer facing entities can build collaboratively
- Understanding the different perspectives from the regions
- Understanding the lay of the laid in the different regions including the key needs of the farmers
- How do we include the value chain in the agronomy conversation? Incorporate the value chain in the dissemination of information to the farmers.

JULIAN RAMIREZ VILLEGAS

- Integrate/develop agronomy data systems (decentralized) with climate predictions at different timescales.
- Ease of use of climate predictions of next 5-10 days, next 3-6-9 months
- Rapid availability and benchmarking
- Better understand the decision-making space

NELE VERHULST

- Where will the data come from to locally evaluate technologies? What is the role of EiA to support/ develop local adaptive research capacity? E.g., with NARS but also other stakeholders that can do research with the right support for design and data collection.

ELKE VANDAMME

FROM A RESEARCH PERSPECTIVE

- EiA needs weather advisories for its climate adaptation objective but; available advisories are not reliable; we don't have competitive advantage/ skill set inhouse to develop/improve ourselves
- How do we align the strategy paper with the prioritization tool?

Shifting time horizon for farmer decision

MULTISECTORAL APPROVAL
EDUCATION FOCUS

- Future opportunistic for research
- Get more predictive in climate crop modelling
- Scalability of models
- Precision of models
- Accuracy/limits

END OF DAY 1 OBSERVERS +ADVOCACY

SUMMARY

- Integrated social protection/social services with efforts to promote adaptive behavior change
- Breakdown silos between ministries
- Using homologs =develop science and development
- Linking adaptations to SDG`s
- Contextualizing generic interventions

EXPERT GROUP II (DAY 1)

RESEARCH

1.Missing issues/points

- Landscape scale. Linkages
  - Landscape as a unit?

- Mapping existing local practices
- Current VS future practices
  - Do they function under future climate?

- Level of readiness of adaptations solutions

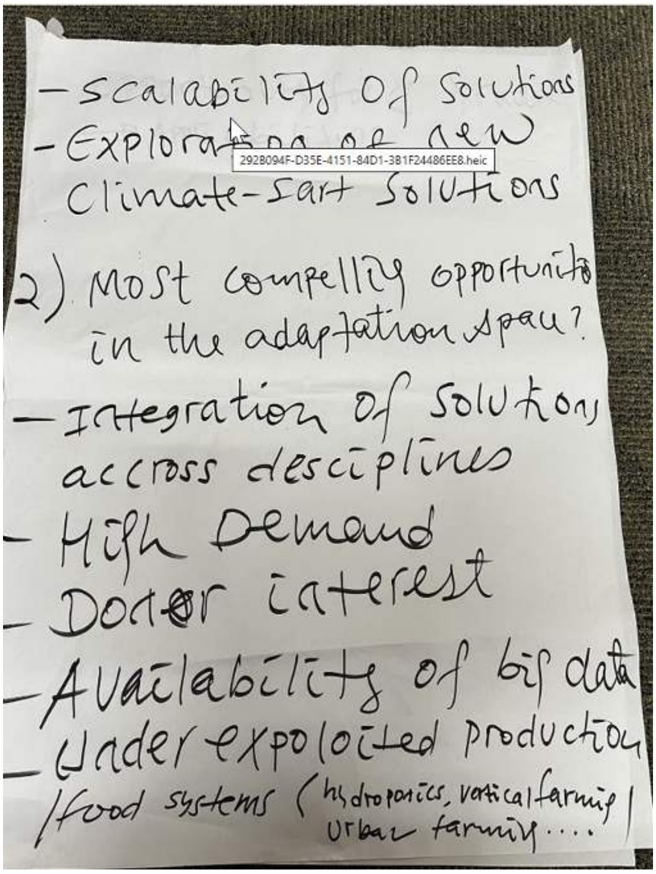
- What are the research gaps?
- Clear scaling strategies for solutions/capacities
- Scalability of solutions
- Exploration of new climate smart solutions

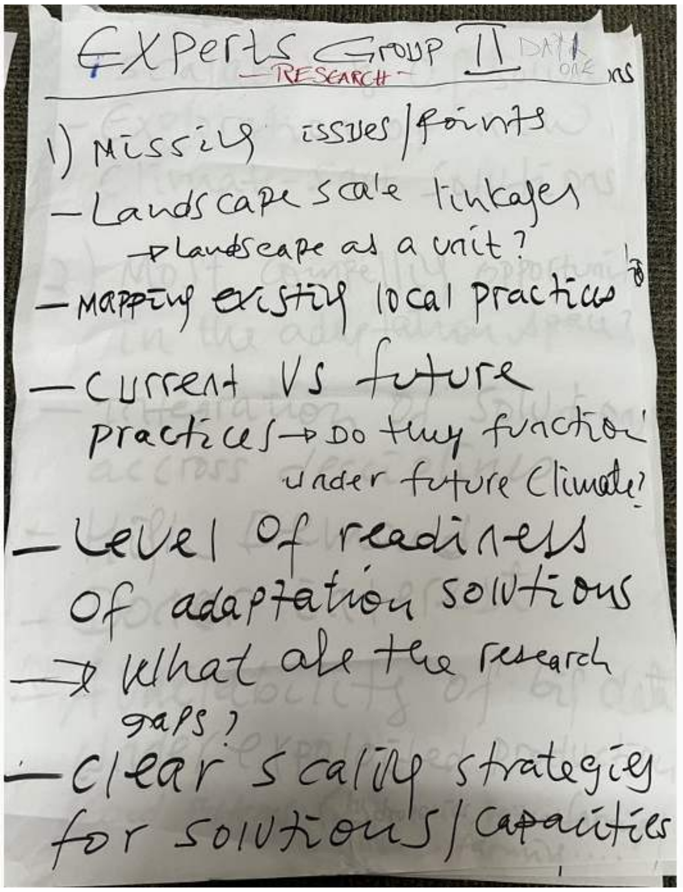
2.Most compelling opportunities in the adaptations and pace

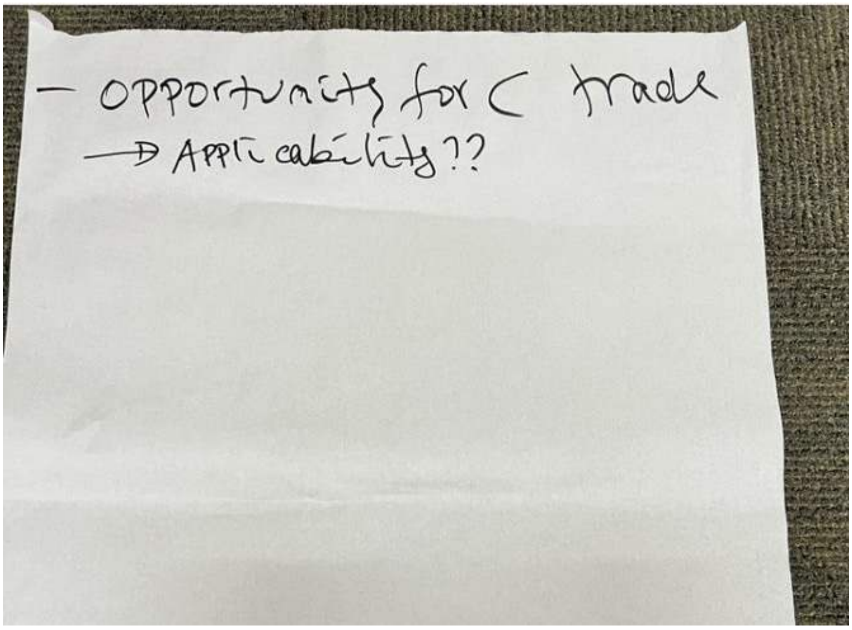
- Integration of solutions across disciplines
- High demand
- Doctor interest
- Availability of big data
- Under exploited productions/Food systems
- Hydroponics, vertical farming/urban farming
- Opportunities for C trade
  - Applicability???

SUMMARY FROM POST ITS

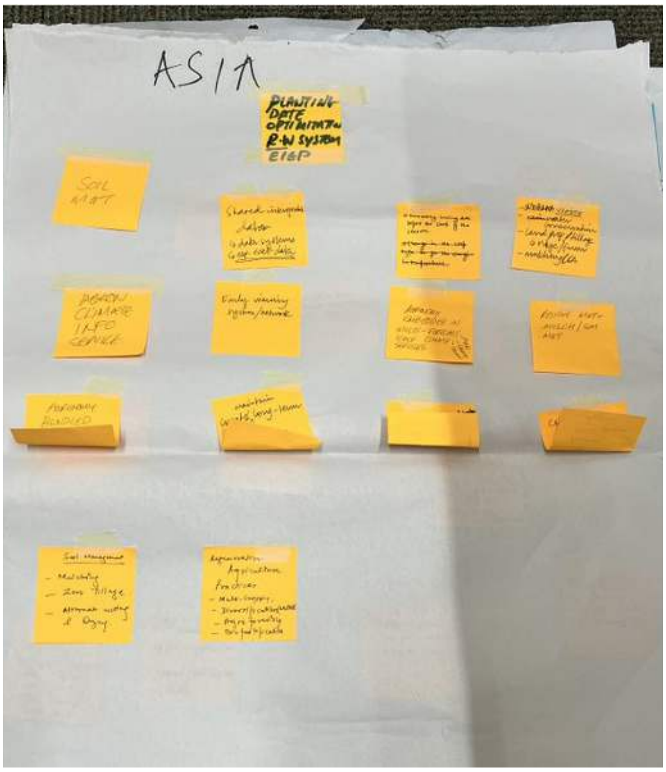
EXPERTS

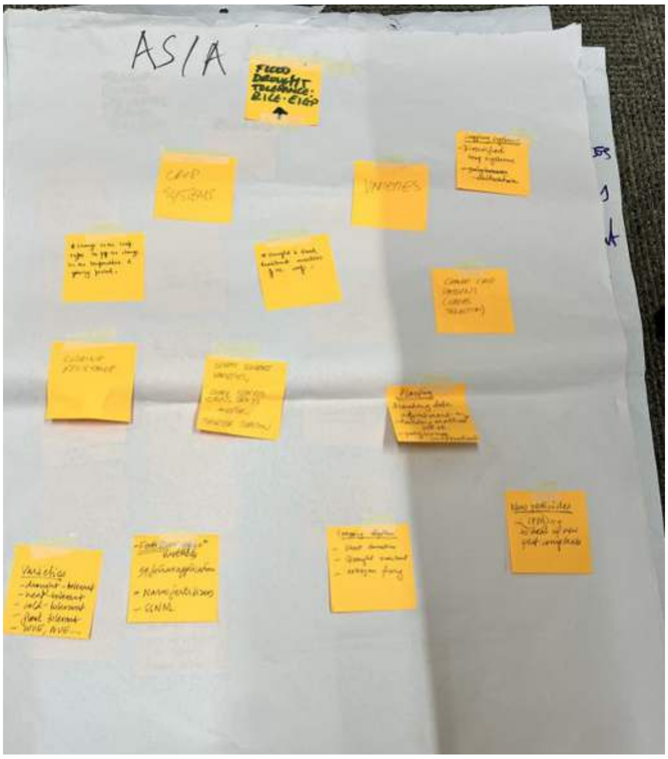


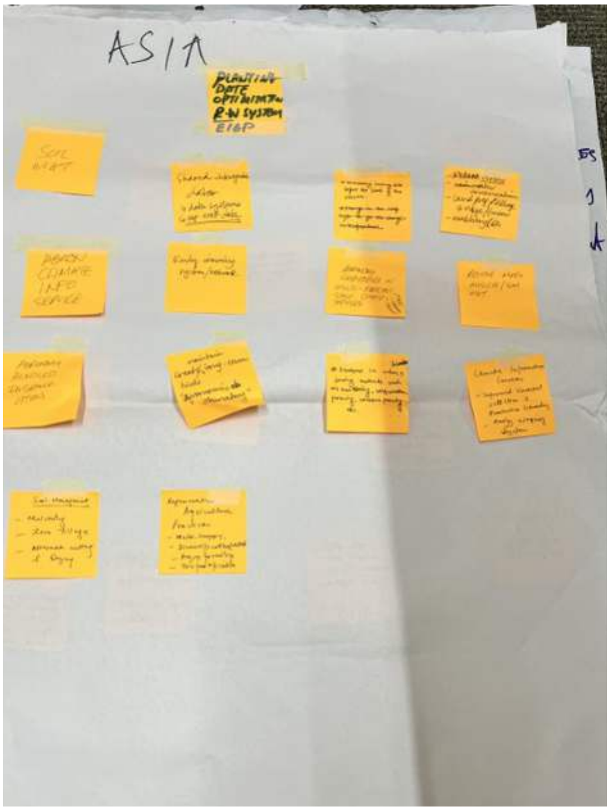


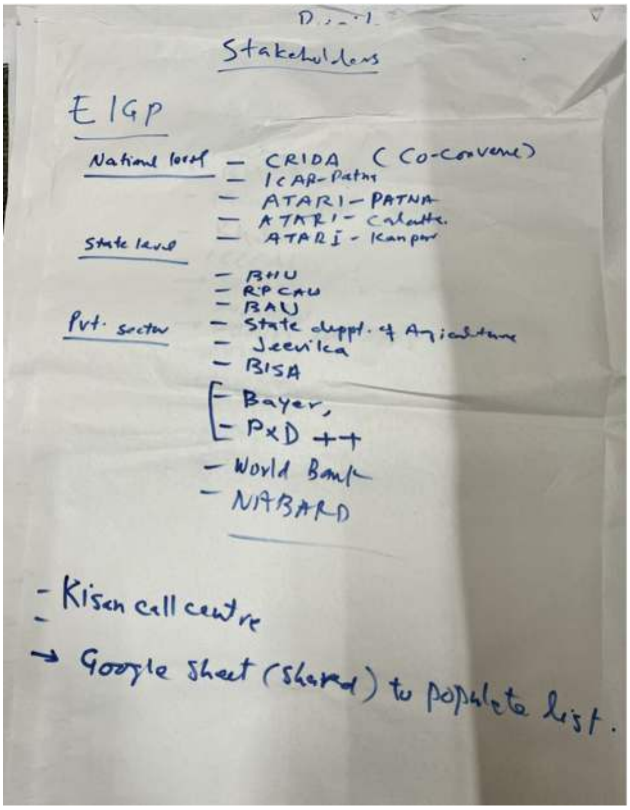


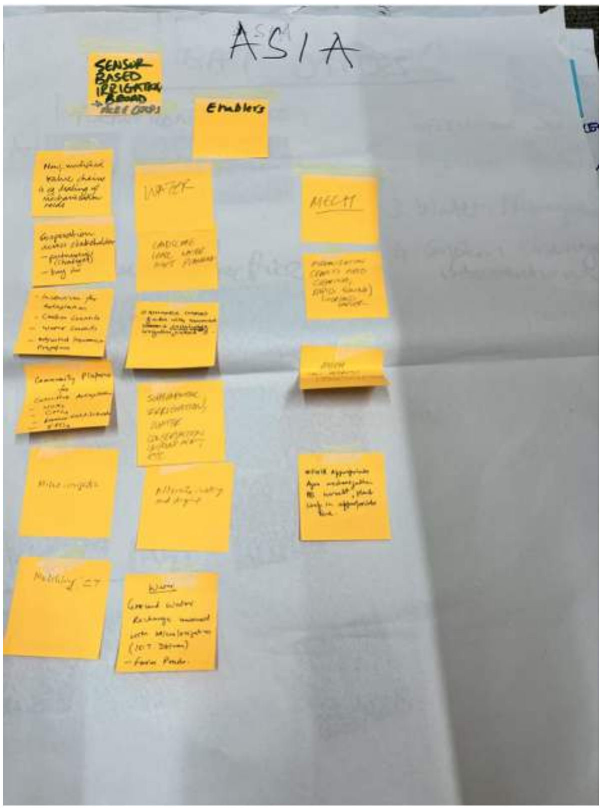
ASIA


ASIA
PLANTING DATE OPTIMIZATION R-W SYSTEM EIGP
SOIL MGMT

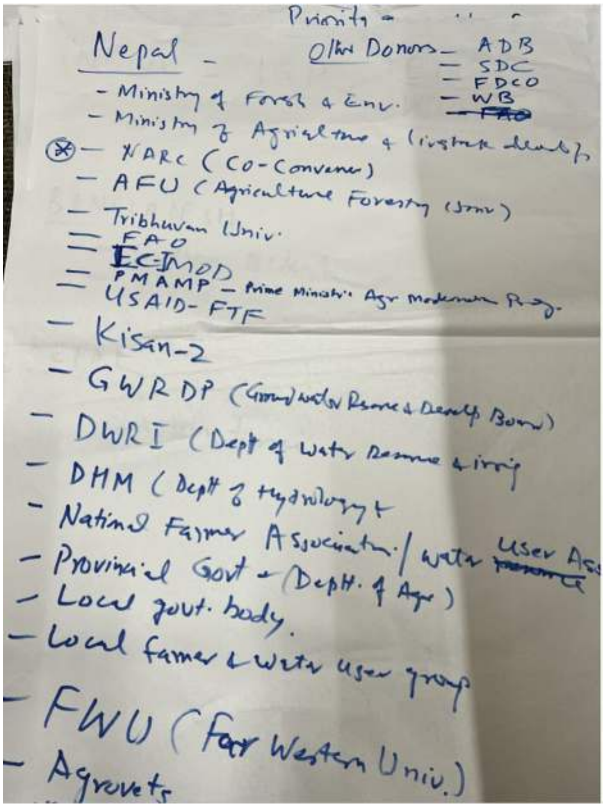

ASIA

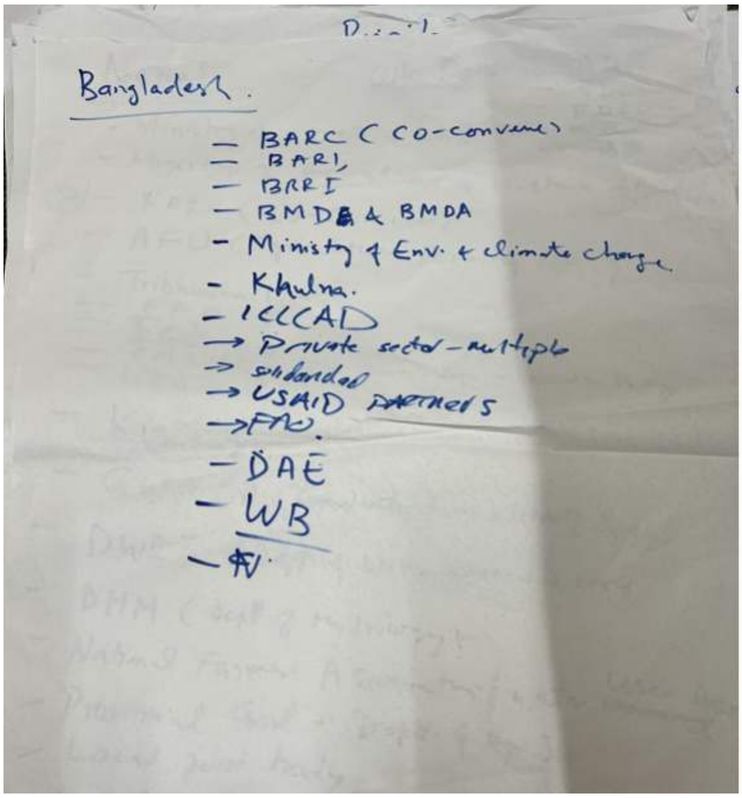

ASIA
PLANTING DATE OPTIMIZATION R-W SYSTEM EIGP

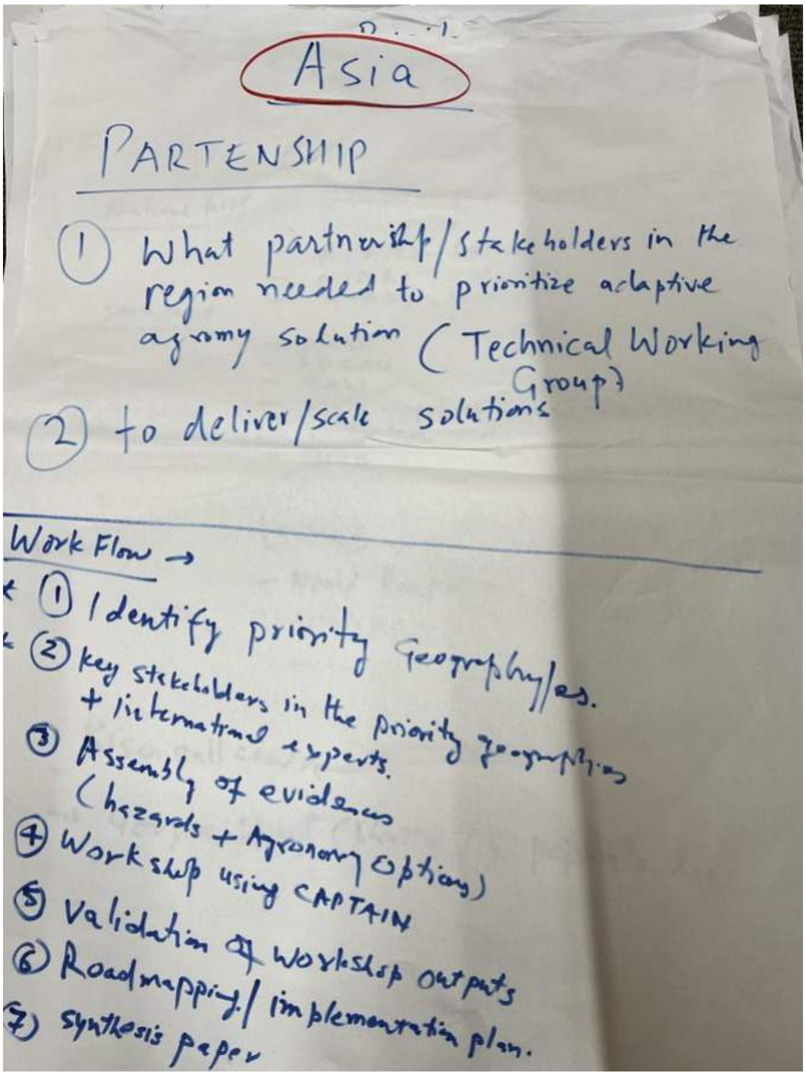

Stakeholders
EIGP
National level – CRIDA (Co-convene)
– ICAR-Patna
– ATARI – PATNA
– ATARI – Calcutta
State level – ATARI – Kanpur
– BHU
– RPCAU
– BAU
Pvt. sector – State deppt. of Agriculture
– Jeevika
– BISA
– Bayer,
– PxD ++
– World Bank
– NABARD
– Kisan call centre
→ Google Sheet (Shared) to populate list.

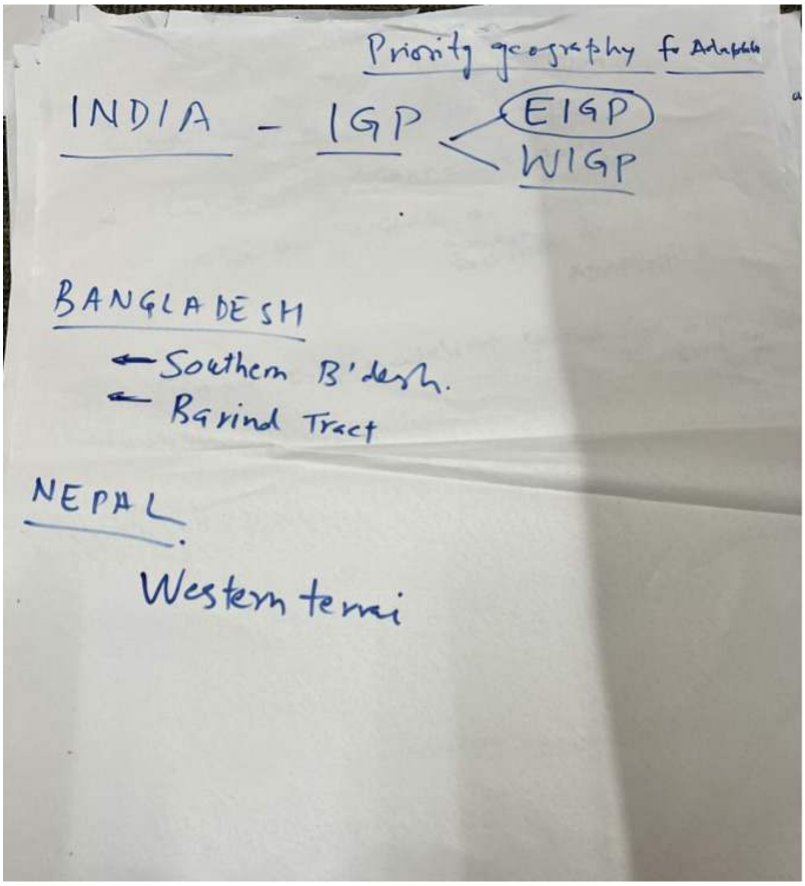

ASIA
SENSOR BASED IRRIGATION
Enablers
WATER
MECH


Hazards
Technical options
ASIA
1. Drought
2. Flood
3. Unseasonal Climate variability
4. Shortened growing Season
5. High temp.
6
Perception & current adaptation data
ty.
7. Cold stress
3C9FC4A5-CF2E-4DD0-A735-EB821A106576.heic
8. Cyclone / Extreme Weather events.

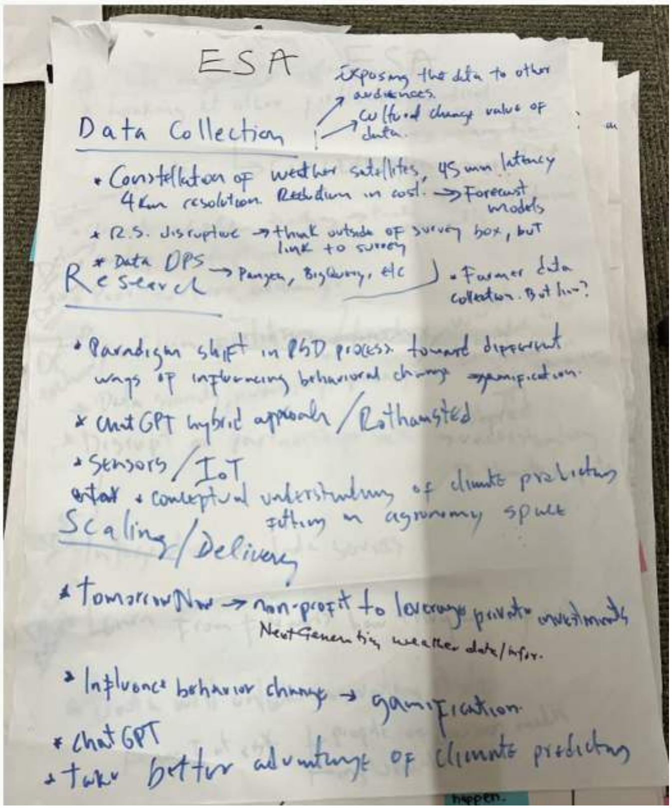

Nepal -
Other Donors - ADB
- SDC
- FDCO
- WB
- FAO
- Ministry of Forest & Env.
- Ministry of Agriculture & Livestock development
- NARC (Co-Convener)
- AFU (Agriculture Forestry Univ)
- Tribhuvan Univ.
- FAO
- ICIMOD
- PMAMP - Prime Minister's Agr Modernization Prog.
- USAID-FTF
- Kisan-2
- GWRDP (Groundwater Resource & Develop Board)
- DWRI (Dept of Water Resource & irrig)
- DHM (Dept of Hydrology &
- National Farmer Association / water User Ass
- Provincial Govt - (Deptt. of Agr)
- Local govt. body.
- Local farmer & Water user group
- FWU (Far Western Univ.)
- Agrovets

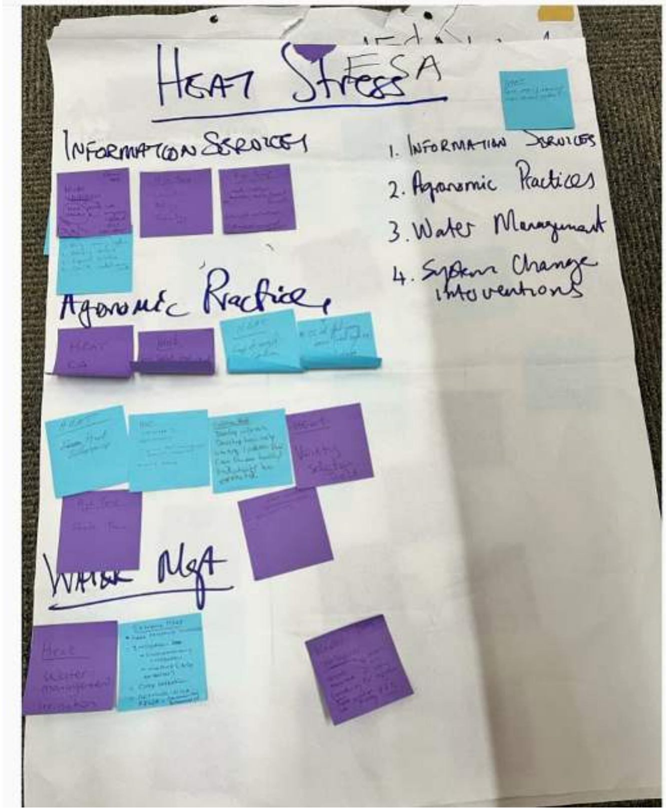

Bangladesh.
- BARC (Co-convener)
- BARI
- BRRI
- BMDA & BMDA
- Ministry of Env. & climate change
- Khulna.
- ICCCAD
→ Private sector - multiple
→ solidaridad
→ USAID partners
→ FAO.
- DAE
- WB

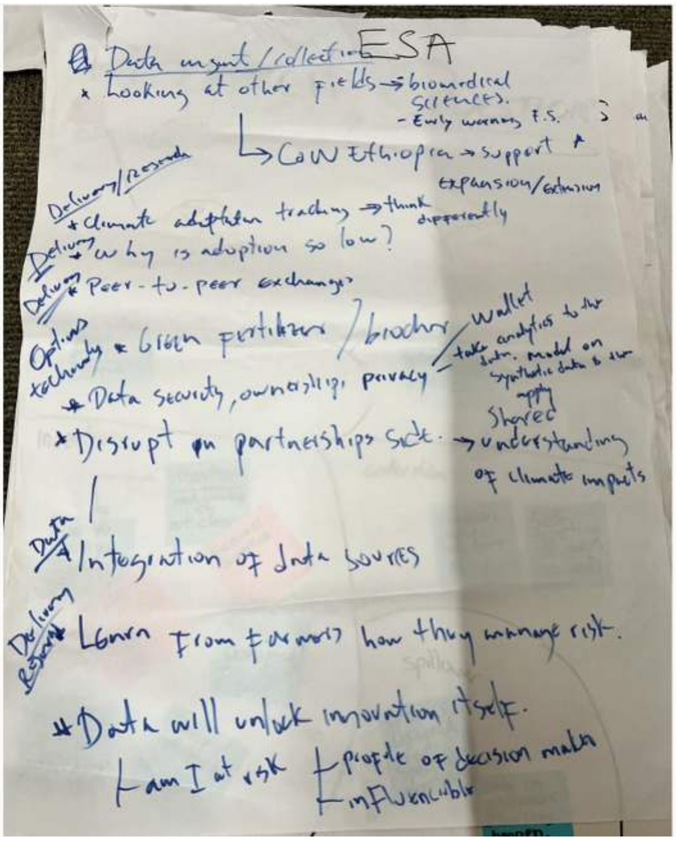

Asia
PARTENSHIP
(1) What partnership/stakeholders in the region needed to prioritize adaptive agronomy solution (Technical Working Group)
(2) to deliver/scale solutions
Work Flow →
(1) Identify priority Geography/ies.
(2) key stakeholders in the priority geographies + international experts.
(3) Assembly of evidences (hazards + Agronomy options)
(4) Workshop using CAPTAIN
(5) Validation of workshop outputs
(6) Roadmapping/implementation plan.
(7) synthesis paper

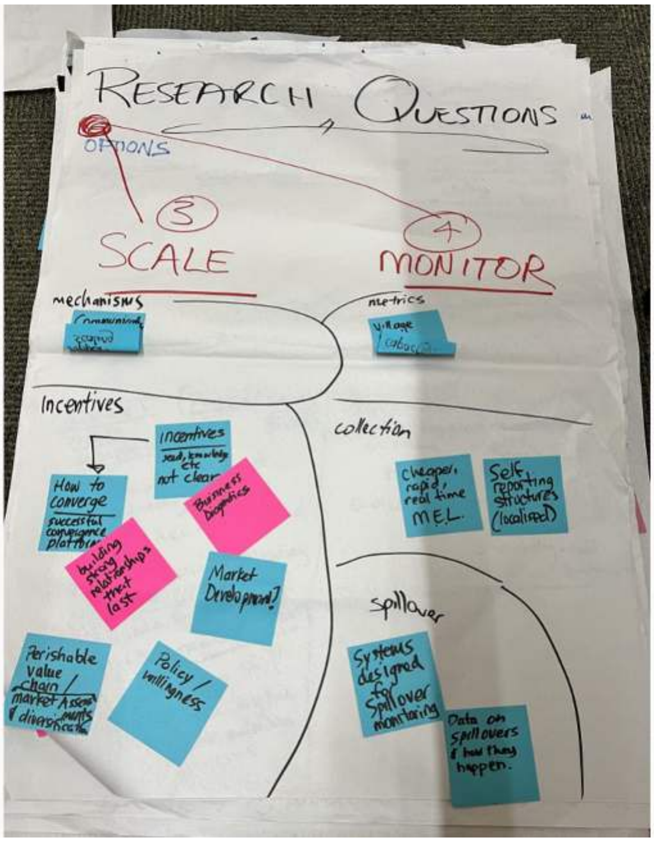

Priority geography
INDIA - IGP
EIGP
WIGP
BANGLADESH
← Southern B'desh.
← Barind Tract
NEPAL
Western terai

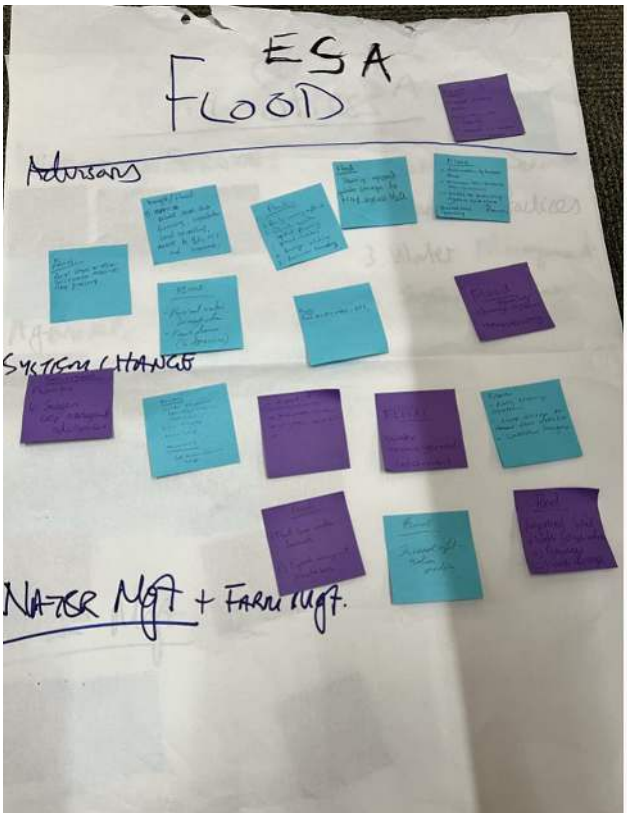
EAST SOUTHERN AFRICA



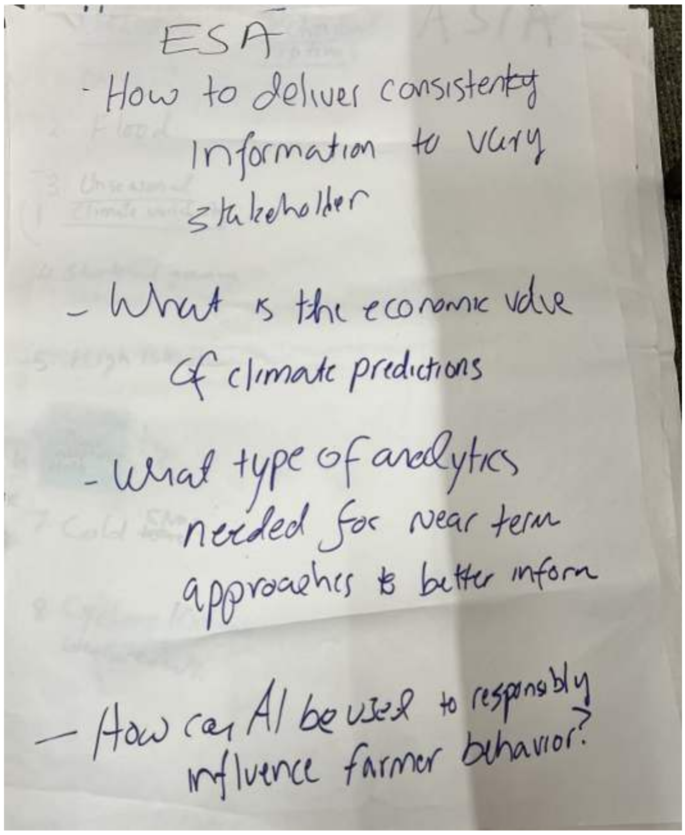




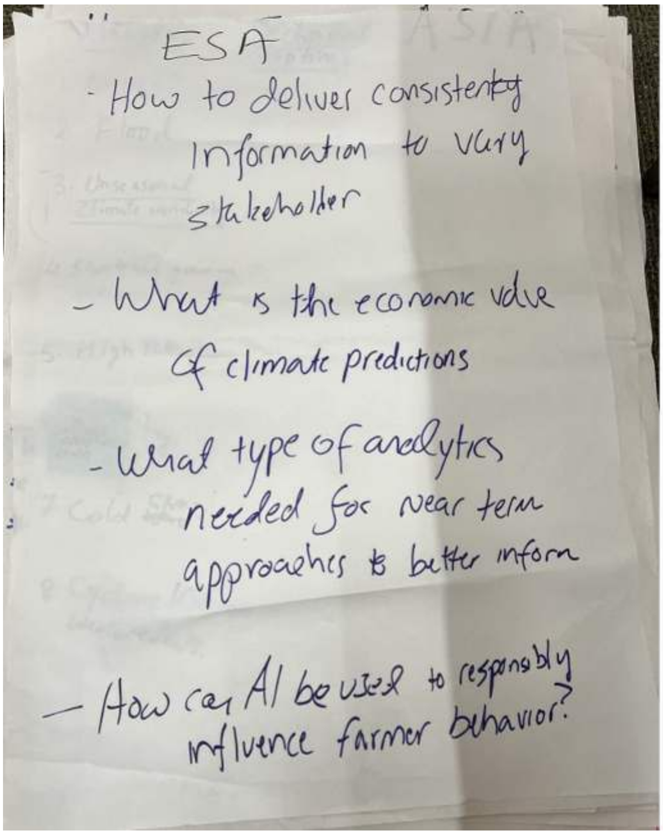




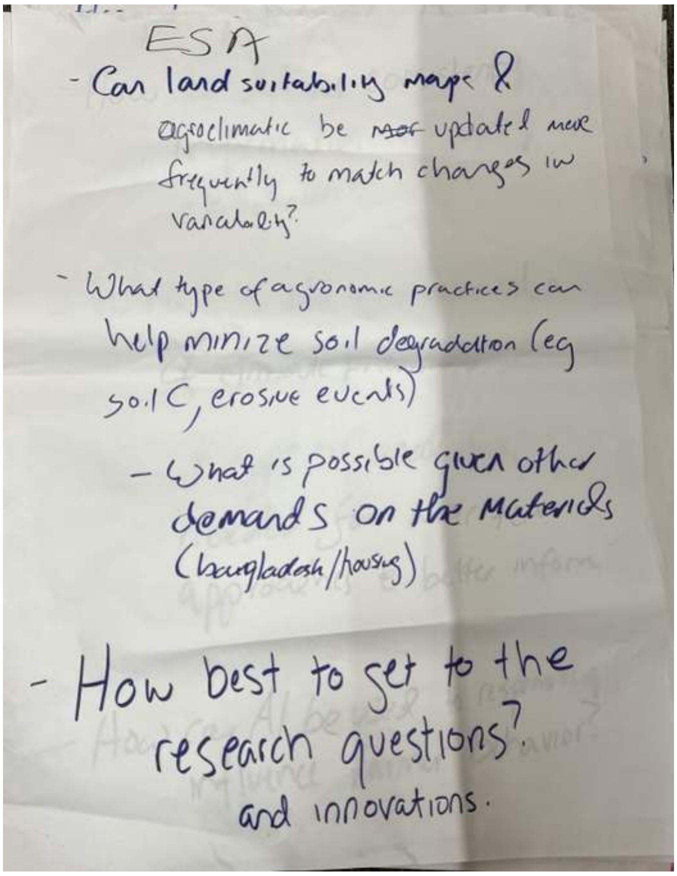
ESA
FLOOD
Advisory
SYSTEM CHANGE
WATER MGT + FARM MGT.



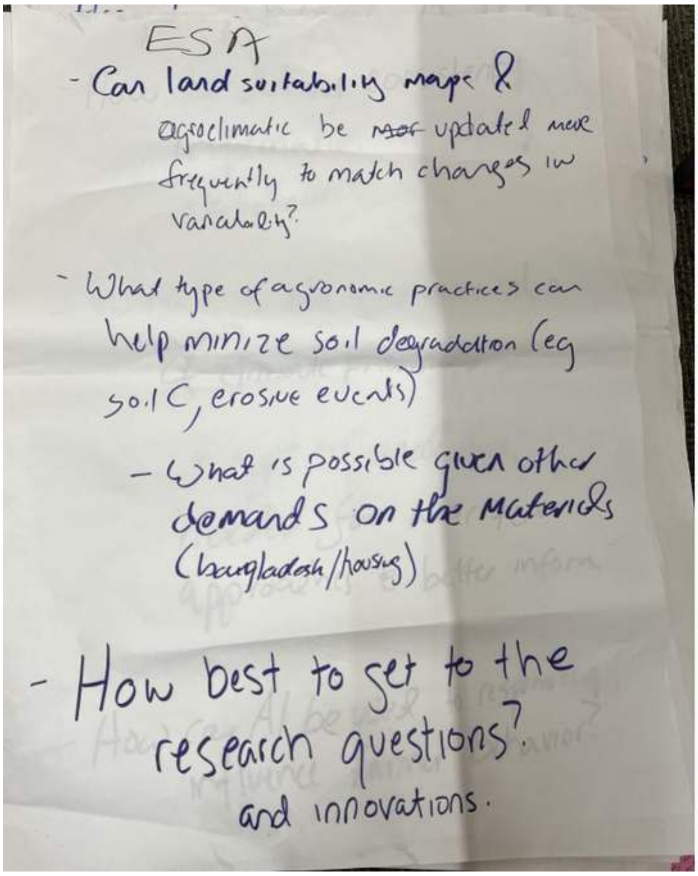
ESA
- How to deliver consistently information to vary stakeholder
- What is the economic value of climate predictions
- What type of analytics needed for near term approaches to better inform
- How can AI be used to responsibly influence farmer behavior?

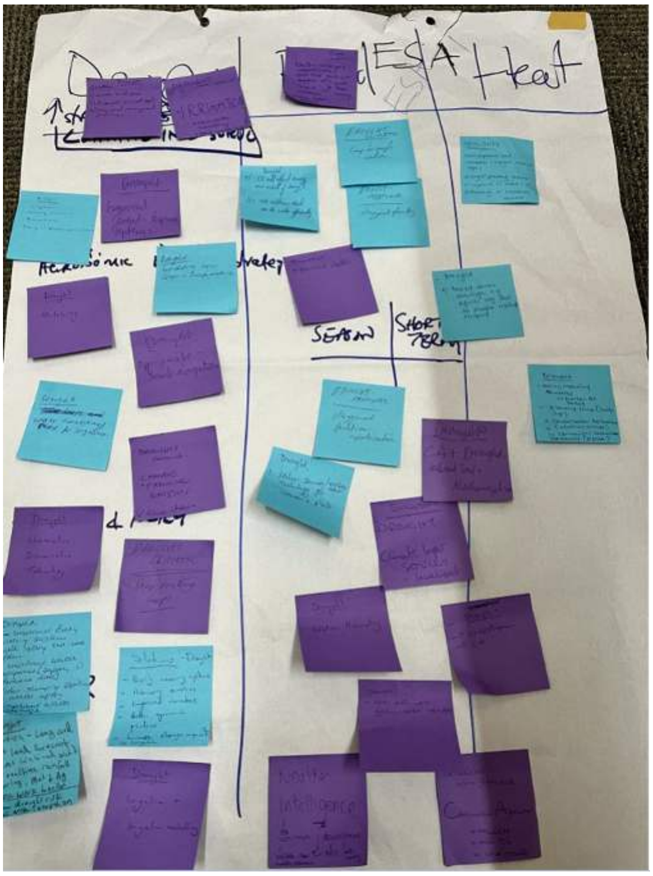


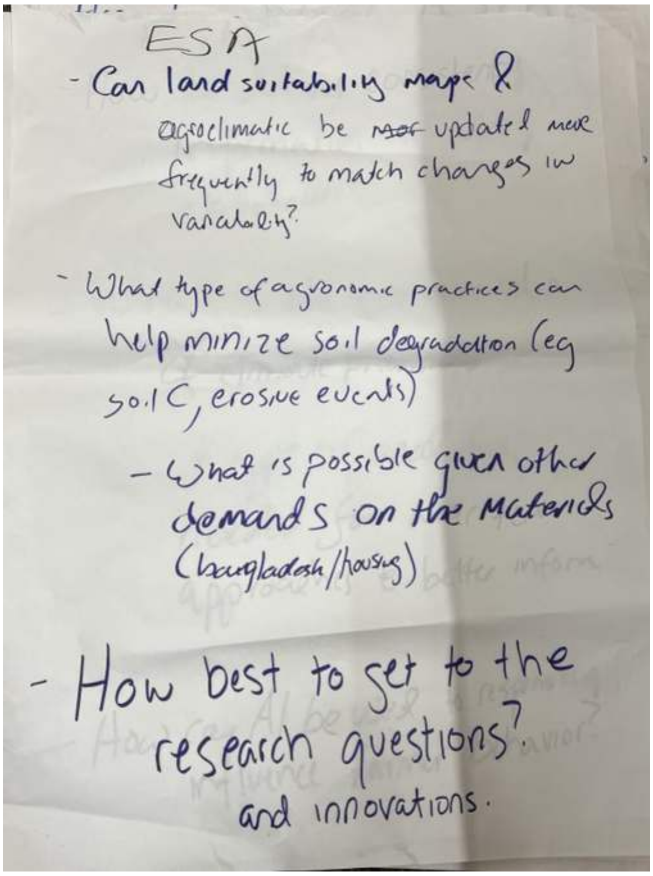
ESA
- How to deliver consistently information to vary stakeholder
- What is the economic value of climate predictions
- What type of analytics needed for near term approaches to better inform
- How can AI be used to responsibly influence farmer behavior?

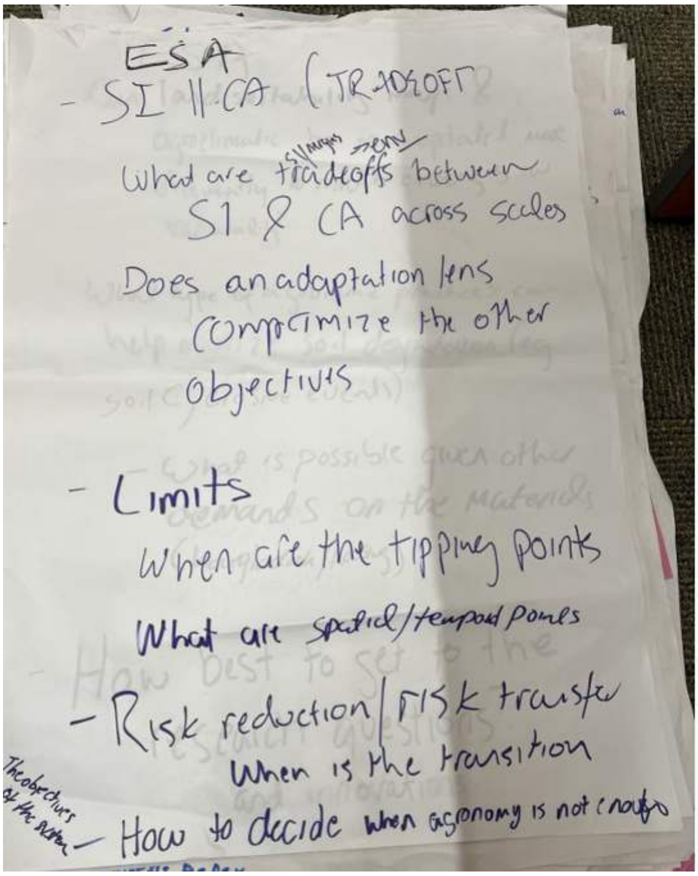


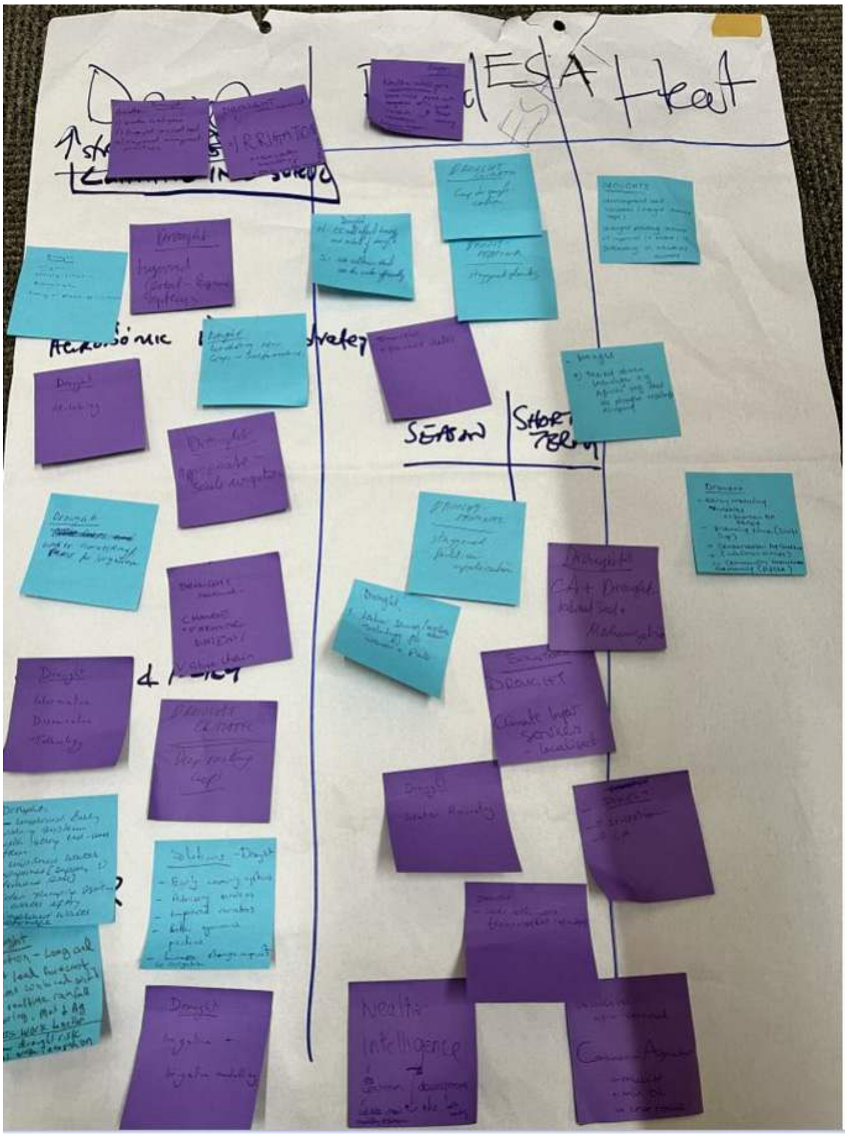
ESA
- Can land suitability maps & agroclimatic be updated more frequently to match changes in variability?
- What type of agronomic practices can help minimize soil degradation (eg soil C, erosive events)
- What is possible given other demands on the materials (bangladesh/housing)
- How best to set to the research questions? and innovations.


ESA
- Can land suitability maps & agroclimatic be updated more frequently to match changes in variability?
- What type of agronomic practices can help minize soil degradation (eg soil C, erosive events)
- What is possible given other demands on the materials (bangladesh/housing)
- How best to set to the research questions? and innovations.

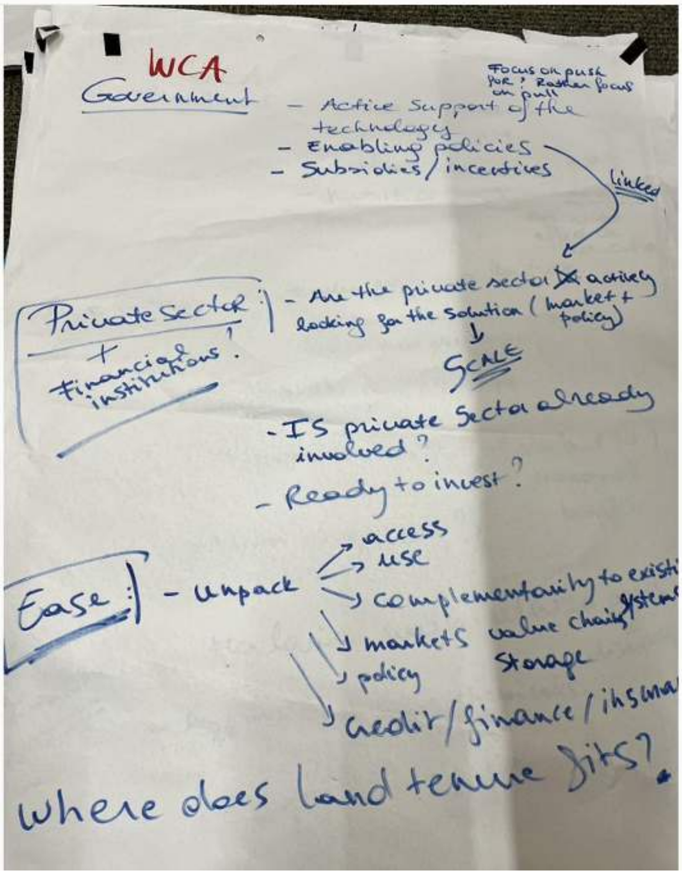

ESA
Heat
SEASON
SHORT TERM

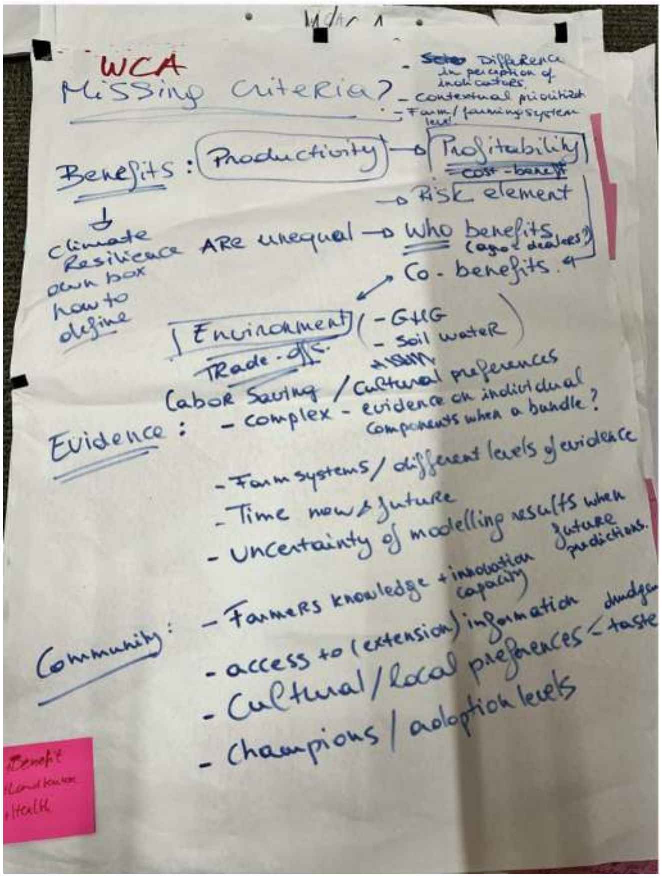

ESA
- Can land suitability maps & agroclimatic be updated more frequently to match changes in variability?
- What type of agronomic practices can help minize soil degradation (eg soil C, erosive events)
- What is possible given other demands on the materials (bangladesh/housing)
- How best to set to the research questions? and innovations.

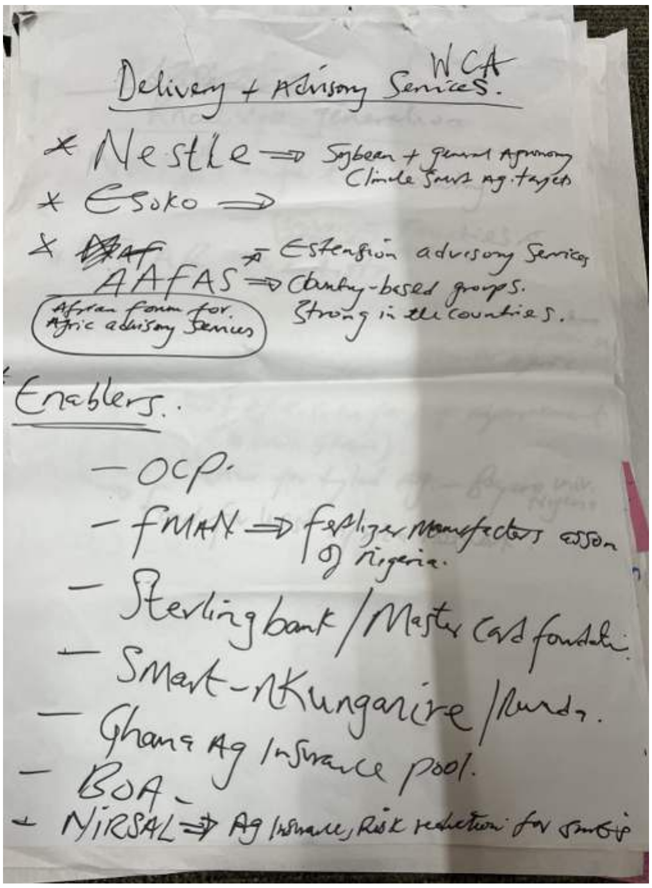

ESA
- SI || CA (TRADEOFF
What are tradeoffs between SI & CA across scales
Does an adaptation lens compromize the other objectives
- Limits
When are the tipping points
What are spatial/temporal points
- Risk reduction / risk transfer
When is the transition
The objectives of the actor
- How to decide when agronomy is not enough

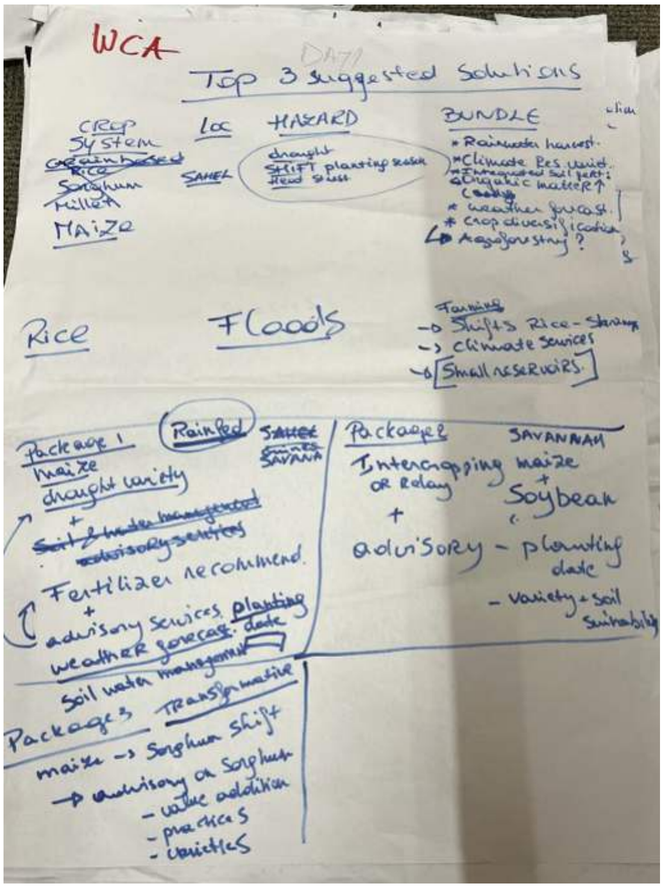

ESA
Heat
Drought
SEASON

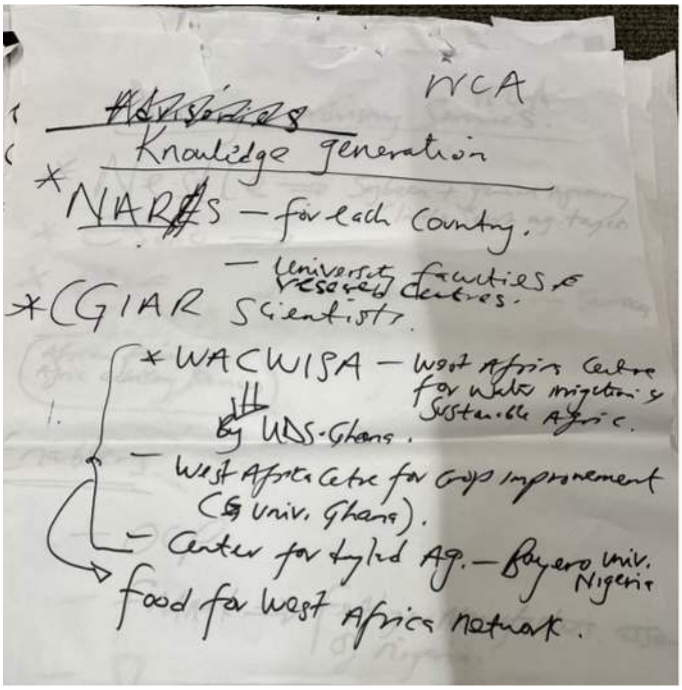
WEST AFRICA

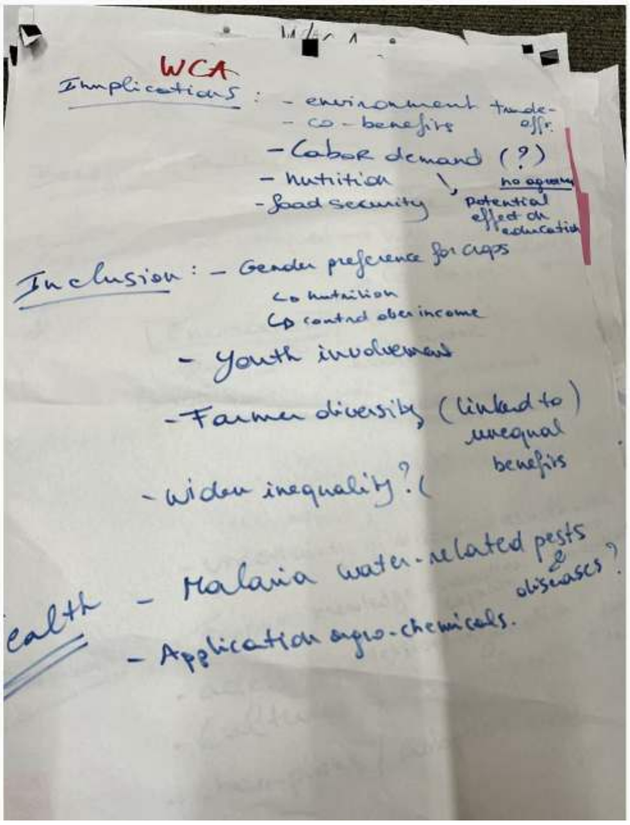

WCA
Government
- Active support of the technology
Focus on push for? Rather focus on pull
- Enabling policies
- Subsidies / incentives
Linked
Private Sector + Financial institutions!
- Are the private sector actively looking for the solution (market + policy)
SCALE
- IS private Sector already involved?
- Ready to invest?
Ease - unpack
access
use
complementarity to existing systems
markets value chains
Storage
policy
credit / finance / insurance
where does land tenure fits?

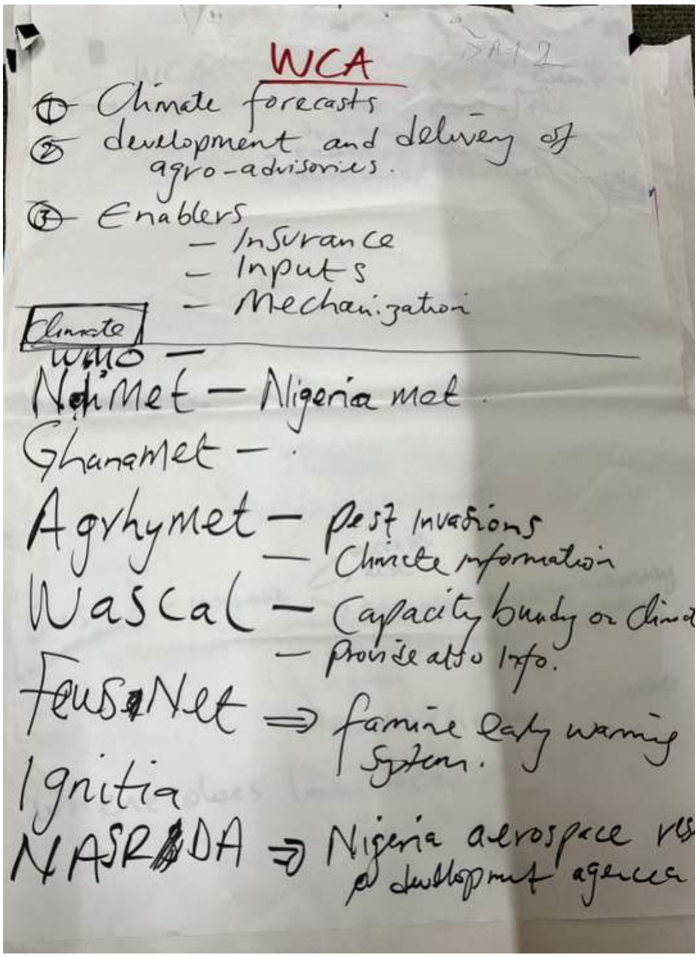

WCA
Missing criteria?
- Difference in perception of indicators
- contextual prioritization
- Farm / farming system level
Benefits : Productivity - Profitability
cost - benefit
- Risk element
Climate Resilience
own box
how to define
ARe unequal - Who benefits
Co - benefits
Environment - GHG - Soil water
Trade-offs
Labor Saving / Cultural preferences
Evidence : - complex - evidence on individual components when a bundle?
- Farm systems / different levels of evidence
- Time now & future
- Uncertainty of modelling results when future predictions.
Community : - Farmers knowledge + innovation capacity
- access to (extension) information
- Cultural / local preferences
- Champions / adoption levels
Benefit
Land tenure
Health

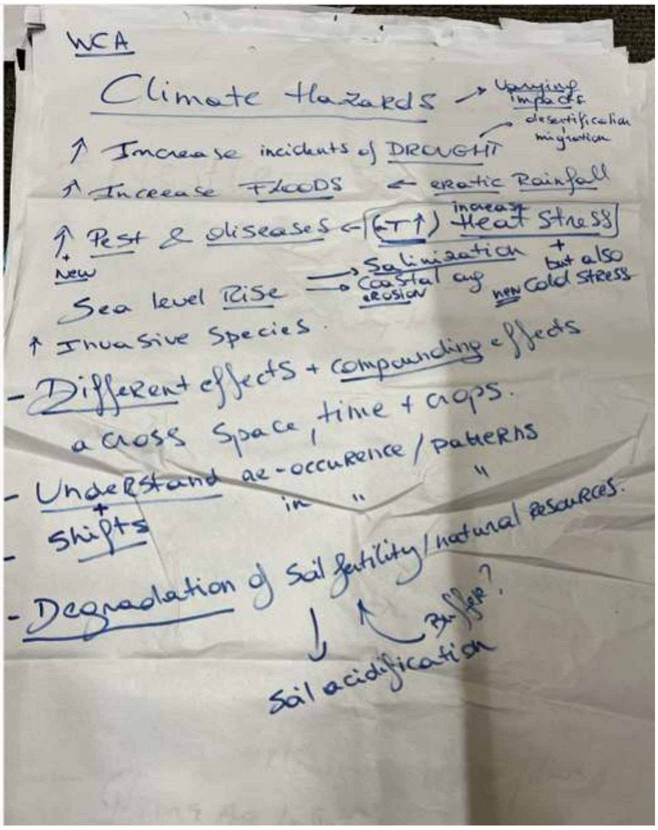

WCA
Delivery + Advisory Services.
* Nestle ⇒ Soybean + general agronomy
Climate smart ag. targets
* Esoko ⇒
* AAFAS ⇒ Extension advisory services
Country-based groups.
Strong in the countries.
African Forum for Agric advisory services
Enablers.
- OCP.
- FMAN ⇒ fertilizer manufacturers assoc. of Nigeria.
- Sterling bank / Master Card foundation
- Smart-Nkunganire / Rwanda.
- Ghana Ag Insurance pool.
- BOA.
- NIRSAL ⇒ Ag Insurance, Risk reduction for SmEs


WCA
Top 3 suggested Solutions
CROP SYSTEM
LOC
HAZARD
BUNDLE
Rice
Sorghum
Millet
MAIZE
SAHEL
drought
SHIFT planting season
Heat stress
* Rainwater harvest.
* Climate Res. varieties
* weather forecast.
* Crop diversification
Rice
Floods
Farming
- Shifts Rice - Swamp
- Climate services
- Small reservoirs.
Package 1
Rainfed
SAHEL
SAVANA
Maize
drought variety
+
Fertilizer recommend.
+
advisory services planting date
weather forecast
Soil water management
Package 2
SAVANNAH
Intercropping maize + Soybean
OR Relay
+
advisory - planting date
- variety + soil suitability
Package 3 Transformative
Sorghum shift
maize → Sorghum
→ advisory on Sorghum
- value addition
- practices
- varieties

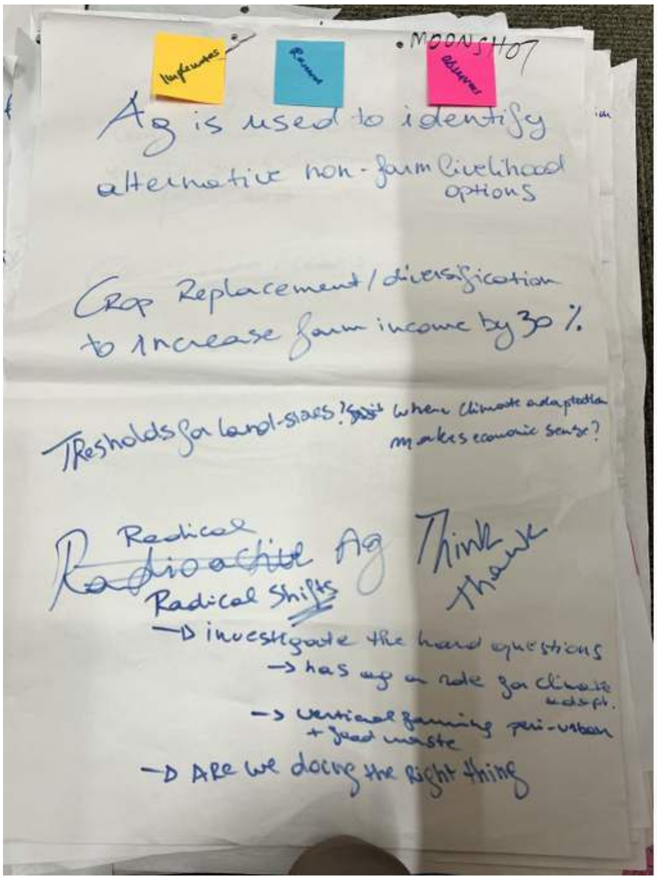

WCA
Knowledge generation
*NARS – for each country.
– universities, faculties & research centres.
*CGIAR Scientists.
*WACWISA – West Africa Centre for Water irrigation & Sustainable Africa.
By UDS-Ghana.
– West Africa Centre for Crops improvement (Univ. Ghana).
– Center for Dryland Ag. – Bayero Univ. Nigeria
Food for West Africa network.

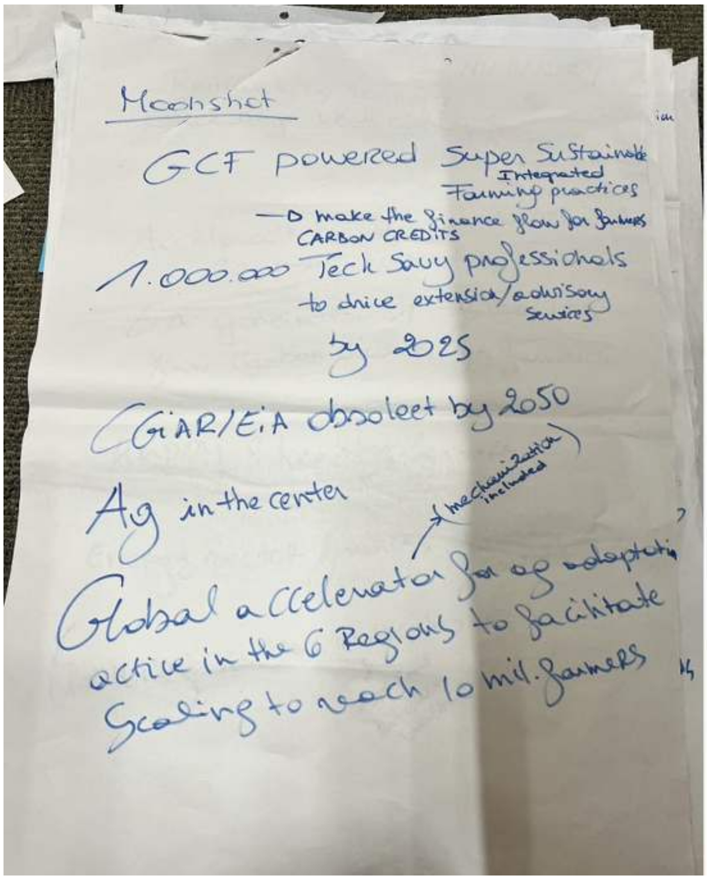

WCA
Implications: – environment trade-offs
– co-benefits
– Labor demand (?)
– nutrition
– food security
potential effect on education
Inclusion: – Gender preference for crops
→ nutrition
→ control over income
– youth involvement
– Farmer diversity (linked to) unequal benefits
– widen inequality?
Health – Malaria water-related pests & diseases?
– Application agro-chemicals.

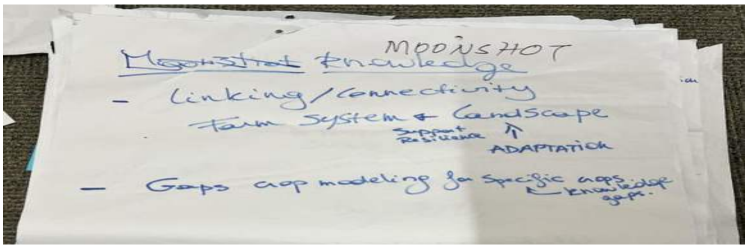

WCA
① Climate forecasts
② development and delivery of agro-advisories.
③ Enablers
– Insurance
– Inputs
– Mechanization
Climate
WMO –
NiMet – Nigeria met.
GhanaMet –
Agrhymet – pest invasions
– Climate information
Wascal – Capacity building on climate
– provide also info.
FewsNet ⇒ famine early warning system.
Ignitia
NASRDA ⇒ Nigeria aerospace res. & development agency

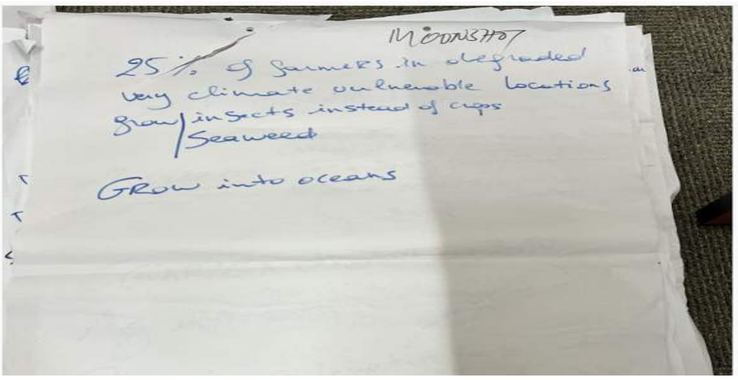

WCA
Climate Hazards → Varying impacts
desertification
migration
↑ Increase incidents of DROUGHT
↑ Increase FLOODS ← erratic Rainfall
↑ Pest & diseases ← (T↑) increase Heat Stress
New
Sea level Rise → Salinization
→ Coastal erosion
+ but also new Cold Stress
↑ Invasive Species.
– Different effects + compounding effects
across space, time + crops.
– Understand co-occurrence / patterns
+ shifts in "
– Degradation of soil fertility / natural resources.
Buffer?
Soil acidification

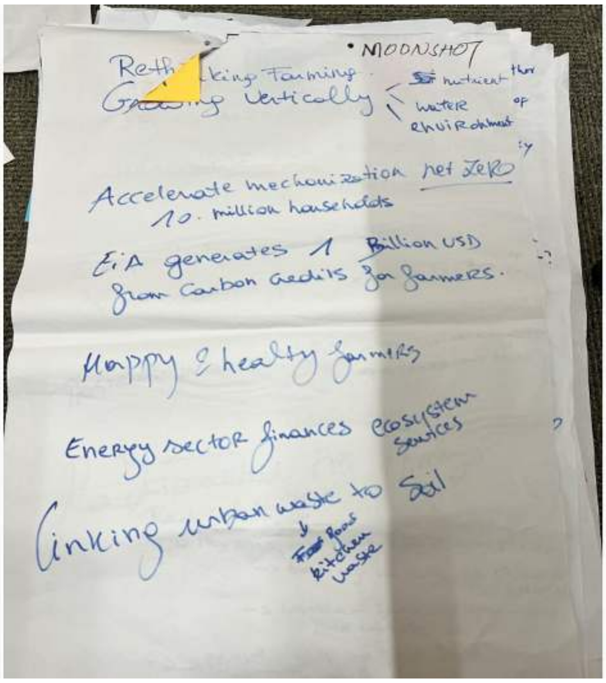
MOONSHOT


MOONSHOT
Ag is used to identify
alternative non-farm livelihood options
Crop Replacement / diversification
to increase farm income by 30 %
Tresholds for land-sizes? where climate adaptation makes economic sense?
Radical
Radioactive Ag
Think thank
Radical Shifts
-> investigate the hard questions
-> has ag a role for climate adapt.
-> vertical farming peri-urban + food waste
-> Are we doing the right thing

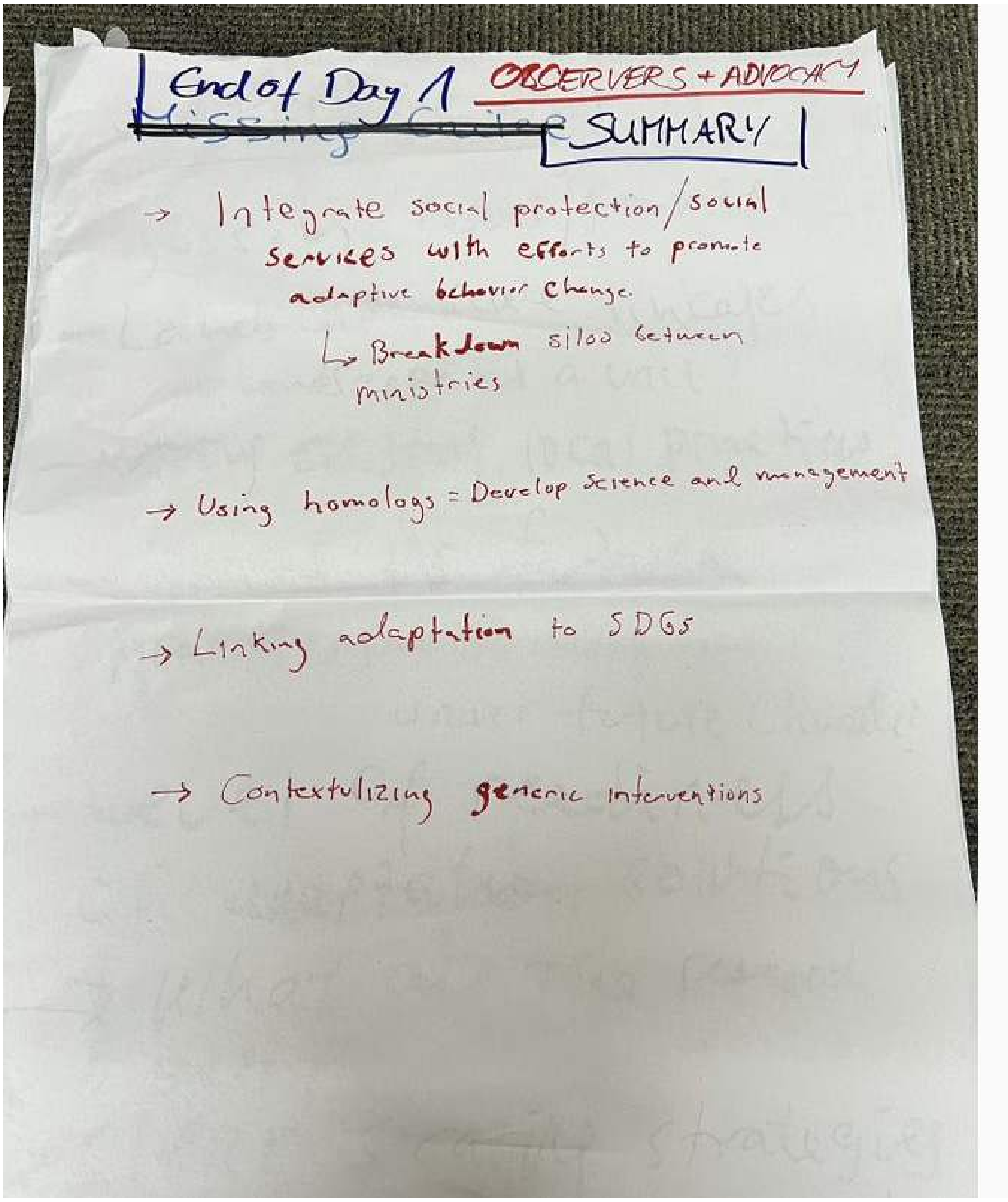

Moonshot
GCF powered Super Sustainable Integrated Farming practices
-> make the finance flow for farmers
CARBON CREDITS
1.000.000 Tech Savy professionals
to drive extension/advisory services
by 2025
CGIAR/EiA obsoleet by 2050
Ag in the center
mechanization included
Global accelerator for ag adaptation
active in the 6 Regions to facilitate
Scaling to reach 10 mil. farmers


MOONSHOT
Knowledge
- Linking / connectivity
Farm System + Landscape
ADAPTATION
- Gaps crop modeling for specific crops
knowledge gaps


MOONSHOT
25% of farmers in degraded
very climate vulnerable locations
grow insects instead of crops
Seaweed
Grow into oceans


MOONSHOT
Rethinking Farming
Growing Vertically
nutrient
water
environment
Accelerate mechanization net ZERO
10. million households
EiA generates 1 Billion USD
from Carbon Credits for farmers.
Happy & healthy farmers
Energy sector finances ecosystem services
Linking urban waste to soil
Food Rooms
Kitchen waste

OBSERVER


End of Day 1
OBSERVERS + ADVOCACY
SUMMARY
→ Integrate social protection/social services with efforts to promote adaptive behavior change.
↳ Breakdown siloo between ministries
→ Using homologs = Develop science and management
→ Linking adaptation to SDGs
→ Contextulizing generic interventions

> **Agronomy directly addresses the climate risks farmers face and provides solutions relevant for practically every crop, farmer, and agro-climate conditions.**

EXCELLENCE IN AGRONOMY
ADAPT INTENSIFY GROW

DR. PETRA SCHMITTER
Principal Researcher –
Climate Change Adaptation
International Water Management Institute - Colombo

TODD ROSENSTOCK
Principal Scientist
Alliance of Bioversity International and International Center for Tropical Agriculture
(Bioversity- (CIAT)