AgMIP Adaptation Teams Start-Up: A CLARE Transition Activity

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Frequently Used Acronyms

AgMIP (Agricultural Model Intercomparison and Improvement Project)
A-Team (Adaptation Team)
BAU (Business as Usual)
CCAFS (CGIAR Research Program on Climate Change, Agriculture and Food Security)
CGIAR (Consortium of International Agricultural Research Centers)
DFID (Department for International Development)
FAO (Food and Agriculture Organization of the United Nations)
FCDO (Foreign, Commonwealth and Development Office)
GCF (Green Climate Fund)
GDP (Gross Domestic Product)
GGCMI (Global Gridded Crop Modeling Intercomparison)
GHG (Greenhouse Gas)
IA (Integrated Assessments)
ICRISAT (International Crops Research Institute for the Semi-Arid Tropics)
IDRC (International Development Research Centre)
IE (Impacts Explorer)
IFPRI (International Food Policy Research Institute)
IMPACT (International Model for Policy Analysis of Agricultural Commodities and Trade)
IPAR (Initiative Prospective Agricole et Rurale)
IPCC (Intergovernmental Panel on Climate Change)
NAP (National Adaptation Plan)
NDC (Nationally-Determined Contribution)
PAS-PNA (Scientific Support Project for National Adaptation Plans)
RAP (Representative Agricultural Pathway)
RCP (Representative Concentration Pathway)
RIA (Regional Integrated Assessment)
SSPs (Shared Socioeconomic Pathways)
UN (United Nations)
UNFCCC (United Nations Framework Convention on Climate Change)
UNDP (United Nations Development Programme)
WUR (Wageningen University Research)

Frequently Used Terms

Crop & Livestock Yields: Crop simulations are used to estimate crop or livestock productivity under current, future and adapted conditions (i.e., current and future climate and current, future and adapted management). The relative yield approach is used to estimate the change in the yield distribution in a population of farms due to climate change or other shocks and/or a change in management (See AgMIP Protocols v7 for details, Rosenzweig et al., 2017).

Farm Net Returns: The TOA-MD model estimates the mean net returns per farm (Currency/Farm/Time). Farm net returns distributions are estimated using farm production, prices, and production costs from each activity in the farm. Changes in mean farm net returns are computed for every simulation experiment.

Poverty Rate: The population Poverty Headcount rate (%) is estimated by the economic model. This indicator shows the proportion of households that are below a poverty line. In the AGMIP-CLARE analyses the poverty line was set at US$ 1/per/day.

Poverty Gap: The population Poverty Gap (%) estimated by the economic model shows the amount of average income as a proportion of farm income that farm households would need to increase in order to be above the poverty line.

Vulnerability: The vulnerability indicator (%) estimated by the TOA-MD represents the proportion of farms in a population that are vulnerable to climate change (i.e., farm households which farm income are at risk of decreasing due to climate change).

Net Economic Impact: The Net Economic Impact (%) is estimated by the TOA-MD by calculating the gains minus the losses as a percent of the mean net farm returns in a population of farms.

Adoption rate: The adoption rate (%) estimated by the economic model represents the percent of adopting farms when a new technology or system is introduced (e.g., an adapted technology). This indicator can be interpreted as the potential adoption rates, without considering other possible factors that may limit adoption.

Food Security: In the AgMIP-CLARE project, the Income Based Food Security (IBFS) indicator (Antle, Adhikari and Price, 2015) was implemented in the TOA-MD. The IBFS (%) estimates the proportion of farms that are below a threshold. This threshold represents the amount of income needed per person to purchase a nutritionally adequate food basket per day. Thus, the population that fall below this threshold are the households that can't afford a nutritionally adequate food basket and therefore, considered food insecure.

Green House Gas Emissions[1]: GHG emissions were calculated following the International Panel on Climate Change (IPCC) guidelines using the Tier 1 and Tier 2 methods (IPCC, 2006) where data availability allowed.

CH4_Enteric Fermentation. Methane emissions (CO_2eq) from enteric fermentation in livestock were calculated following the Tier 2 methods for cattle, and Tier 1 for other livestock types, where animal numbers were multiplied with their methane emission factors. For cattle, the energy requirements for maintenance and different activities (pregnancy, lactation, work, growth) of the different animal types were considered together with the feed-dependent methane conversion factor. The values for these parameters were derived from the IPCC report using information on body weight, lactation and growth.

CH4_Animal Manure and waste, direct and indirect (CO_2eq). Emissions from animal waste and manure management were calculated with the Tier 1 methods. For methane, this consisted of multiplying the animal numbers of different types with their specific methane emission factor. For N_2O emissions from collected manure, we considered both direct and indirect (after volatilization) N_2O emissions by applying the IPCC emission factors and loss fractions for dry lot and solid storage to stall-fed and other feeding regimes respectively.

N2O_Soil (direct & indirect) and CO2_fertilizer (CO_2eq). Tier 1 methods were also used for the emissions from managed soils, where we considered direct N2O emissions from N inputs to agricultural soils, including the application of synthetic fertilizer, animal manure and crop residues left as mulch. Direct N_2O emissions from urine and dung deposition during grazing were also considered. Indirect N_2O emissions were included for atmospheric deposition from volatilized N and for leaching and runoff losses.

Total GHG: Total Green House Gas emissions (CO_2eq) are estimated by adding N_2O, CH_4 and CO_2 emissions from crop-livestock systems.

[1] GHG emissions were only estimated for the crop-livestock system in Zimbabwe.

1. Abstract

Low productivity and low farm income regions of Ghana, Senegal, and Zimbabwe are continuing to experience high poverty rates and food insecurity. The AgMIP Adaption Teams Project (A-Teams Project) analyses of impacted farm systems in each country show that climate change may impact farms differently. Drier conditions, whether warmer or cooler, are more likely to negatively impact crop and livestock yields. Wetter conditions, even if warmer, may increase yields of some crops. The magnitude of climate impacts depends on how farmers manage their crops (e.g., access and quantity of inputs used) and other bio-physical conditions (e.g., inherent or derived soil fertility). Crops like groundnuts could benefit from climate change owing to effects of CO_2 fertilization, especially if these crops are a large share of total farm returns. However, even in cases with positive impacts of climate change (i.e., average net gains) vulnerability, poverty and food insecurity rates remain high.

It is generally understood that agricultural development based on policy and interventions that consider both national goals and regional (sub-national) needs is likely to improve farmers' livelihoods at present. Here, we share findings on tools and methods that can help decision and policy makers discern policies and interventions to offset negative impacts *with* climate change. In particular, a 'Sustainable Development' pathway that was assessed in Ghana, Senegal, and Zimbabwe provided higher benefits to farmers and made the system more resilient to climate change through increased farm net returns, and decreased poverty and food insecurity rates. Further, we find that the tools and methods can also be applied in the interest of more equitable implementation of agricultural development strategies to ensure that all farmers, even the lesser resourced, will benefit.

Agricultural pathways are likely to have different effects on different farm types. Thus, the analysis of contrasting agricultural pathways for the heterogeneous farming systems in a region should result in more meaningful assessments of impact to sub-groups (strata) of the population studied. Similarly, adaptation packages that are responsive to the conditions experienced by sub-groups could be prioritized through the government's National Adaptation Plan (NAP) process, as they have been tested for their ability to address specific contexts of the heterogeneous farm systems studied at present, as well as in the future.

Adaptations that are based on a single strategy (e.g., use of improved cultivars, change of planting dates, etc.), are not enough and in some cases may result in negative impacts. Adaptation packages need to include interventions or policies that would enable and motivate the successful adoption of the proposed strategies (e.g., access to input and output markets). Conversely, if agricultural development fails to improve farming system conditions through policies and interventions (e.g., improving soil fertility), the benefits of adaptations might be small, or in some cases could increase inequality within a population of farmers in a region.

The analyses also demonstrated that environmental, socio-economic, and bio-physical trade-offs will also need to be considered in the design of policies and interventions to maximize

adaptation-mitigation co-benefits, and in so doing, contribute to Nationally Determined Commitments (NDCs) to climate change mitigation. Methods to better assess trade-offs (e.g., national scale crop modeling, analysis of national agroecosystems, etc.) as well as those to rigorously link multiple models (e.g., regional and national economics) were also tested in the overall scope of work, and provide encouraging results, but will require further testing and development for fuller implementation. Mitigation strategies may need to be promoted with incentives to increase adoption (e.g. payment for eco-system services) where trade-offs are difficult to overcome.

The A-Teams Project results suggest that understanding the response of farming systems to both national policy and technological interventions as well as climate change, will require assessments of representative farming population subgroups at the local (sub-national) level, to help inform actionable policies at the national level. The AgMIP approach to assessing climate change and adaptation impacts can provide science-based information to support the design of policies at the national level, as well as interventions targeted to specific farming systems, while at the same time contributing rigor to forward-looking planning processes like the NAPs and NDCs.

Exploration and adoption of the methodologies are greatly benefited by the process of co-development of policy and information briefs written in the language of policymakers. The co-creation of outreach and communication matter in a step-wise approach by stakeholders and scientists results in co-ownership of the results, which can then be broadly and confidently shared by scientists and stakeholders alike via documents, presentations, and well-designed, user-friendly web-based platforms such as the AgMIP Impacts Explorer.

2. Background and Research Objectives

During 2020-2021, with support from DFID, FCDO, and IDRC for its Climate Change Adaptation and Resilience (CLARE) program, the AgMIP A-Teams Project adapted and extended the AgMIP Regional Integrated Assessment (RIA) methodology to a national scale so as to better inform climate adaptation planning and decision-making in the agricultural sector in Ghana, Senegal, and Zimbabwe. The expanded application of RIA to the national scale has the potential to increase the uptake and impacts of the research results. AgMIP developed RIA to conduct rigorous transdisciplinary and multi-model assessments of how climate change would affect smallholder farming systems in one region of each study country during a prior phase of work that was supported by DFID (2011-2017; AgMIP DFID). AgMIP A-Team Project formed adaptation research teams (A-Teams) in Ghana, Senegal, and Zimbabwe, three of the seven countries in Sub-Saharan Africa and South Asia established under AgMIP DFID.

The AgMIP A-Team Project has three objectives. (1) Build on prior AgMIP work to improve national stakeholder capacity to develop National Adaptation Plans (NAPs) as well as policies and adaptation strategies that would advance adaptation to climate in agriculture based on science. (2) Increase the in-country AgMIP A-Team capacity to co-develop information products of value to national and international stakeholders. The A-Teams refined best practices for effective stakeholder engagement, co-produced information relevant for planning and decision making at the national level, and implemented monitoring and evaluation in each country to establish a basis on which to expand outcomes and impacts. (3) Share AgMIP data and research results broadly to demonstrate the unique capabilities of co-developed science and policy. The teams organized virtual briefings and workshops with stakeholders, with whom they also co-designed policy and information briefs, presentations, and contents for the Impacts Explorer v2.0.

Each A-Team, led by a research scientist who effectively involved regional and national stakeholders in the prior AgMIP DFID phase, engaged key national stakeholders to co-produce information that is relevant to planning and decisions using extended versions of three decision-support tools developed during AgMIP DFID: The AgMIP Impacts Explorer (IE), Representative Agricultural Pathways (RAPs), and Adaptation Packages (APs). The A-Teams collaborated with stakeholders to expand these tools to address planning and decision making at the national level, whereas prior AgMIP DFID work focused on one region in each country. The A-Team work is augmented by Base Team contributions. Base Teams investigated data and methods to support linkages between regional and national scales of study, each in partnership with one or more A-Teams. Topics included (a) Utilizing a national-scale gridded crop model utilizing regional inputs together with additional national-scale information for estimating maize production in Ghana; (b) Testing the use of outputs from a regional economic assessment of national RAPs in Senegal as inputs to a national scale economic model; (c) Investigating remotely sensed data for information to explore agroclimate characteristics of sub-regions in Zimbabwe; (d) Developing a refreshed and user-friendly prototype Impacts Explorer v2.0 designed to expand the relevance of the tool with selected global, national, and regional content and methods; (e) Establishing a monitoring and evaluation framework, including A-Team Project baselines in each country; (f) Documenting the methodology for developing RAPs at multiple geographic and political scales; (g) Creating a new research framework for Integrated National and Regional Assessments (INaRA), that includes an adaptation and mitigation co-assessment component; and (h) Estimating the emissions from an A-Team adaptation package to explore linked adaptation and mitigation strategies for a fuller assessment approach. In so doing, the AgMIP A-Teams Project fulfilled a fourth objective, included in Figure 2.0.

3. Outcome Overview

The CLARE program seeks to enable actors in planning, programme implementation, policy and research. The goal is to use a range of evidence-based options to enhance and support communities' livelihoods in the face of climate challenges in ways that benefit the most vulnerable women and men. This section summarizes the A-Teams Project methods, the main

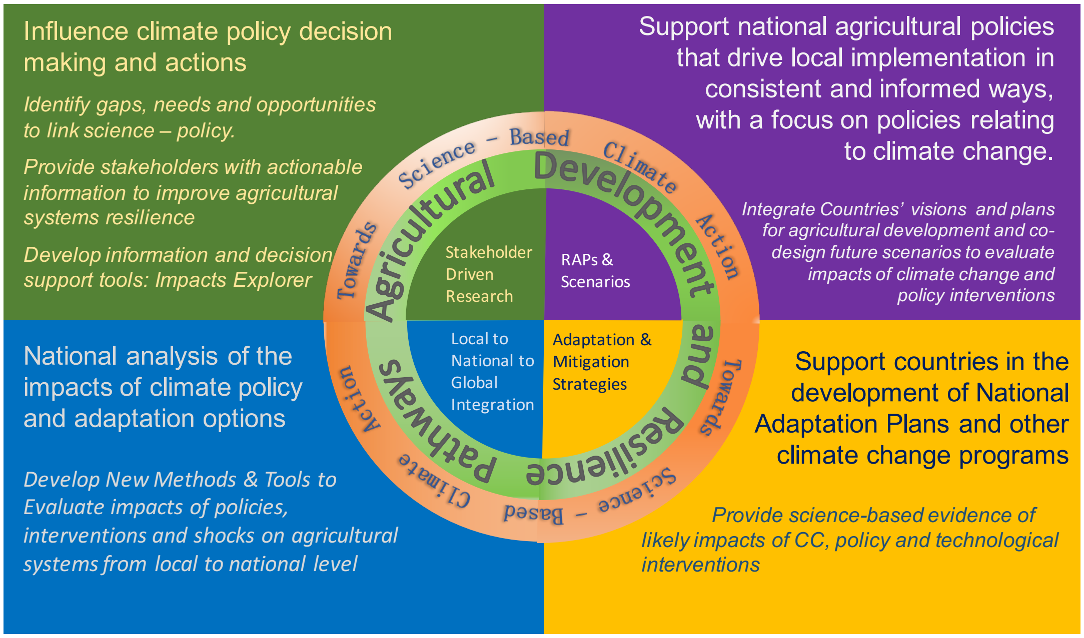


Figure 2.0. Diagram of AgMIP A-Team Project objectives, with examples of actions and intended outcomes.

contributions to these aims from the A-Teams in Ghana, Senegal, and Zimbabwe, and changes arising from the stakeholder engagement process in each country.

The AgMIP A-Team Project conducted enhanced stakeholder interactions in policy and research by involving a diverse set of agricultural sector stakeholders and actors with expertise in NAP processes in the three project countries. The stakeholders and actors were drawn from government ministries as well research and academia, and interactions were documented in baseline surveys, interviews, and workshops. The enhanced stakeholder interactions resulted in the formation of RAPs that were used as inputs into socioeconomic model simulations to investigate climate impact and adaptation options, relevant for policy formulation. Technical work on climate and agricultural production was carried out by the A-Teams as well and contributed to the climate impacts and adaptation evidence base presented to the stakeholders (see also Figure 3.0). The simulation approaches were effective in addressing numerous "what if" questions of the actors, providing a firm foundation for further developing their NAPs.

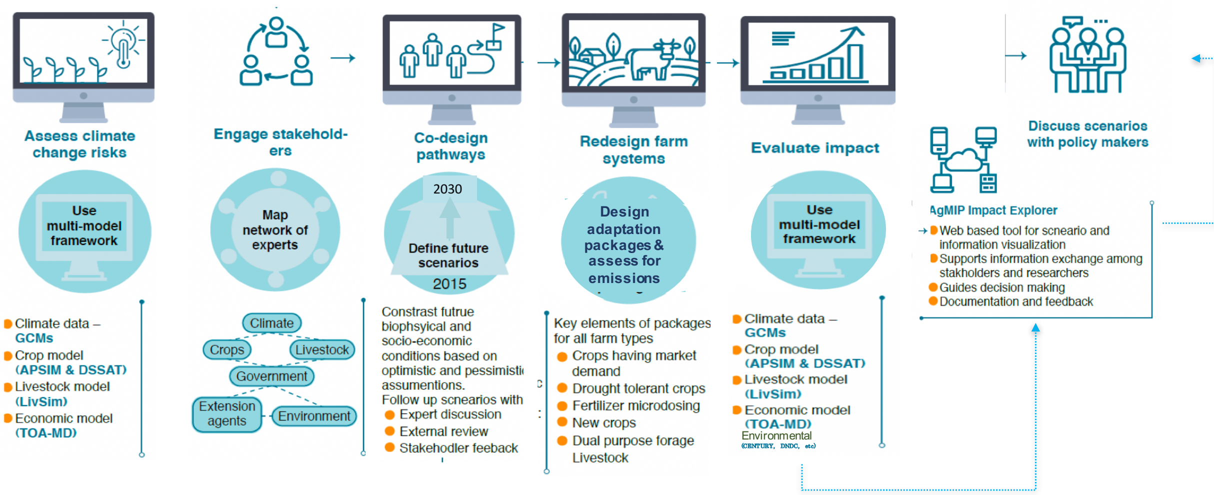


Figure 3.0. Flow diagram of the AgMIP Regional Integrated Assessment (RIA) approach (after Valdivia et al, 2019).

3.1 Ghana

This project enabled an enhanced integration of the various stakeholders and actors involved in climate change impact on agriculture and livelihoods in Ghana. The actors included the Crop services department of the ministry of Food and Agriculture (MoFA); the Environmental Protection Agency (EPA), and the CCAFS Policy platform.

The outcomes of the interactions fed into socioeconomic models that for investigating various climate impact and adaptation options, which are relevant for policy formulation. For example, data from agronomic and socio-economic and climate from Navrongo, Ghana served as input for the models. The results demonstrate that current production systems will leave about 50% of households vulnerable to climate change. However, depending on the RAP followed by the government, vulnerability could decrease to between 40 to 45%.

The results of the simulations led to discussions on the usefulness of the AgMIP RIA methodology in contributing to the NAP planning process. Key entry points identified include media engagement, workshop for stakeholders, community engagement, and the use of visualization and information materials (e.g., policy briefs, infographics, audio-visuals, posters). Stakeholders confirmed the utility of the RIA, particularly in assessing the economic feasibility of the range of adaptation strategies that are currently available, as to inform their selection for investment decision making. Stakeholders requested the training of more scientists on the RIA methodology so as to extend its use to additional components of the agriculture landscape and in so doing, better support decision making. The need for capacity building of stakeholders was also stressed in the interest of better appreciation and interpretation of outputs from the methodology for policy and decision-making processes.

Story of Change

Interactions with stakeholders led to rich knowledge sharing on developing plausible future scenarios for agricultural development. Key strategies that can contribute to bridging the science-policy gaps in the agriculture sector were also identified. Stakeholders and A-team members identified current and likely future challenges in the agricultural sector; co-developed 3 plausible agricultural development pathways; engaged critical discussion on simulation outputs; and, refined key messages from the research. The stakeholders also committed to help disseminate research output at various engagement platforms, as well as the Impacts Explorer and website.

Stakeholders request that the methodology be scaled to the major agricultural farming systems in Ghana. This requires capacity building for more scientists to take up the evolving AgMIP modeling and assessment tools. Capacity building for policy and decision makers on the interactive science approach is also needed for effective co-development engagement.

Partnerships with the climate change desk of the MoFA Crop Services Department (CSD) and the EPA are deepening. These are the major actors in the climate change adaptation planning process in Ghana. The CCAFS Science Policy Platform, also a major actor in the climate change adaptation planning, invited the A Team to join a proposal development workshop targeting support from the Green Climate Funds (GFC; September, 2021). As a result, AgMIP methodologies are included in the overall package.

The EPA representative, who also coordinates the NAP framework, indicated that the methodology is the kind their unit needs to screen the feasibility of the various adaptation strategies. They specifically requested the integration of agro-forestry as an adaptation and the inclusion of mitigation assessments of the various adaptation packages to provide evidence and base support to the NAP and NDC processes to reduce national emissions while adapting to the impacts of climate change.

The implementation of this project has also influenced the academics on the team. Engagement with faculty in the Departments of Agricultural Extension and Agricultural Economic & Agri-Business is underway, with the intent of creating awareness of the data, methods, and tool and their potential to enhance related studies. Discussions are also underway to include aspects of AgMIP data, models, and tools in "*Agricultural Systems Simulation and Modelling*", a postgraduate course hosted at the University of Ghana Department of Soil Science.

3.2 Senegal

Senegal is located in a semi-arid region and has been facing the effects of climate change and variability for several decades, which particularly affect sectors such as agriculture, fishing and tourism. Family farmers are exposed to these risks and uncertainties that regularly threaten their survival. It is in this context that the Government of Senegal has initiated a process to find adaptation and mitigation solutions in the most vulnerable sectors, including agriculture. The tools, methodologies and processes developed successively by AgMIP-DFID and the AgMIP A-Teams Project have come at the right time according to several stakeholders, in particular public decision makers.

Following the national workshop organized by IPAR, the Ministry of Environment and Sustainable Development invited AgMIP to collaborate more with the different partners in order to integrate its methodological approach (RIA, RAPS, APs) in the ongoing (and future) studies on adaptation, in particular in the framework of the elaboration of the NAP for the agricultural sector. Interactions with experts, particularly in the design of RAPs scenarios and sharing sessions with decision-makers, have paved the way for the integration of these AgMIP tools and methods.

By engaging stakeholders in co-design pathways, AgMIP has, at the same time, contributed to building their capacities, especially in terms of forward-looking approaches to policy making. The capacity building efforts on the foresight approach, and on scenario building with stakeholders, have triggered a strong awareness among the different stakeholders. Many are now convinced of the crucial role of foresight scenarios in the agricultural sector, particularly in climate change adaptation planning.

Senegalese civil society has launched a Dynamic for an Agroecological Transition in Senegal (DYTAES). This renewed interest in agro-ecology has provided a good opportunity to use the results of the Sustainable Development (SD) scenario to improve the long-term resilience of agricultural systems to various climate shocks. Based on the income-based food security indicator, this scenario generates a significant reduction in poverty and food insecurity. AgMIP, through its results, has raised awareness on the benefits of investing in agroecology development.

Story of Change

From AgMIP-DFID to the AgMIP A-Teams Project, interactions with decision-makers and other stakeholders interested in climate change issues have progressively integrated the results, tools, methodologies and processes proposed by AgMIP. A few benchmarks help to identify key stages of the changes underway.

The Ministry of agriculture, the Parliamentary Network for the Protection of the Environment in Senegal (REPES) and IPAR organized a High-level workshop on capacity building for decision makers on the theme "*Climate change and agriculture in Senegal: Role of policy makers in the implementation of the Plan Senegal Emergent (PSE)*". This event raised Members of Parliament's awareness about the AgMIP DFID results in Senegal, with a focus on "*Climate change and Senegalese agricultural pathways and their implications for public policy*". The final declaration of the workshop included the decision of the MPs to: (i) Work in synergy with the National committee on climate change (COMNACC), the science-policy dialogue platform on climate change, IPAR, and REPES for a strengthening of the multi-stakeholder dialogue on climate change; and (ii) Support research programs on climate change.

Another high-level stakeholder meeting engaged government representatives, civil society organizations, international organizations, COMNACC, members of Parliament, representatives of farmers' organizations, think tanks and research organizations to share and discuss results from the AgMIP DFID RIA. Key outcomes of the meeting included a call to incorporate the AgMIP results in the "*Intended Nationally Determined Contribution of Senegal under the UNFCCC*" under revision, a request for scientific support to the National Committee on Climate Change through capacity building, backstopping in technical reports, and participation in policy dialogue. Finally, the National committee on climate change (COMNACC) decided to include IPAR on the list of delegates to attend the 46th Session of the Subsidiary Body for Scientific and Technological Advice (SBSTA) of the United Nations Framework Convention on climate change (UNFCCC) in Bonn, Germany.

The Support Project for Science-based National Adaptation Planning in francophone Sub-Sahara African Least Developed Countries (LDCs) built on AgMIP-DFID experience and results to launch a set of studies aimed at preparing the NAP process in Senegal.

The collaborative research of the AgMIP A-Teams Project coordinated by IPAR has contributed to strengthening the science-policy partnership under the leadership of the Ministry of Environment and Sustainable Development and the National Committee on Climate Change (COMNACC). It has helped to strengthen the capacities of actors involved in the process of developing the national plan for adaptation to climate change in the agricultural sector by providing an approach and tools and above all by highlighting the importance of the prospective tools proposed in the development of RAPS.

Today, Senegalese policymakers at the Ministry of Development and Sustainable Development acknowledge that AgMIP provides a powerful decision-support tool within the reach of higher level decision-makers, to figure out what needs to be done now to prepare for the most desirable outcomes, moving away from Business as Usual and addressing the most intractable obstacles in a structural manner.

3.3 Zimbabwe

Climate change aggravates multiple challenges in Zimbabwe, such as poverty, food insecurity and health risks. The impacts of climate change on agriculture and vice versa is dynamic. There is therefore a need to continuously investigate the interaction, understand the vulnerability of the agriculture sector, address barriers to agriculture, and develop realistic adaptation strategies - especially for semi-arid areas with high climatic risk. The AgMIP A-Teams Project provides tools, methodologies, data and messages for experts and decision makers to understand the current and plausible future agriculture states/scenarios and inform national adaptation planning in agriculture. Research is central to this transformation of the agricultural systems.

Experts and policy decision makers in Zimbabwe acknowledge that the AgMIP integrated assessment tools, methods, and processes are vital in contributing to the development of coherent approaches to climate resilience and sustainable development. This was borne out of the several AgMIP efforts in Zimbabwe that created useful products and services. These were developed through consultative processes with multidisciplinary technical experts and decision makers, with influential roles in climate and agricultural policy processes. Through the AgMIP A-Teams Project, scientists engaged with national actors/technical decision-makers in government and related institutions in systematic diagnoses of agriculture challenges, co-developing and validating scenarios, simulation results and key messages, and creating a framework for bringing research outputs into use (practice, action and policy-making).

From this process, national stakeholders realize that Zimbabwe can build on existing structures, networks and opportunities for science to contribute to national climate/agriculture policy and support local level adaptation interventions in the agricultural sector. A series of entry points have been identified that can make use of the AgMIP integrated assessments, tools, methodologies and processes to build national climate research capacity and transform the agriculture sector in Zimbabwe.

Specifically, the Climate Change Management Department (CCMD), as the national authority and focal point for climate action, proposed to facilitate integration of AgMIP approaches and results into the broader climate discourse including through formulation of Zimbabwe’s 2022 NAP, the NDC implementation action plan, and through climate change adaptation project formulation. This can support the revitalization and capacity development of existing research organizations, including the local universities as well as the Agricultural, Research, Innovation and Development Directorate Services (formerly DRSS).

Working through development agencies and multi-donor consortia (e.g., the Zimbabwe Resilience Building Fund, ZRBF) can widen the use of the scientific evidence base provided by the AgMIP A-Teams by using data being collected for ‘climate-proofing’ agriculture. Through collaboration with government institutions like Agricultural Extension Services (AGRITEX), Meteorological Service Department (MSD), and the Zimbabwe National Water Authority (ZINWA), adaptation measures developed and tested by the AgMIP A-Teams Project can be incorporated into local-level demonstrations and training programs, strengthening provincial staff and stakeholders.

Story of Change

From the start to the end of the AgMIP DFID and AgMIP A-Teams Project phases, strategic experts (with strong technical expertise and roles in climate policy advisory) were engaged for consultation in setting up simulations, feedback on results, policy messages, and outreach strategies. The user-oriented research design created enabling conditions to tackle climate change through an inclusive and systematic approach. Focal areas for deeper investigation and adjustment were jointly identified. Dialogue created around the scenarios helped to identify and find ways to bridge policy gaps, using scientific data and information.

The AgMIP A-Teams Project has strengthened important research-policy partnerships with key national actors such as the CCMD as the focal point for overseeing and facilitating climate action, with implementation through the Ministry of Agriculture and Ministry of Industry. Partnerships with regional research organizations such as Lupane State University and Matopos Research Institute strengthen the links to knowledge generation, application and policy influencing. The implementation, with learning processes, allows new opportunities to emerge, with joint ownership of planning and progress. Working with the key national actors/stakeholders, our A-Team was able to develop quality policy briefs and to draft project concept notes through the CCMD for review and onward submission to funding partners.

The CCMD now has the role of reviewing research outputs and integrating those into the national climate action processes, including through the GCF, as well as processes for updating NDCs and NAPs, supporting the dissemination of outputs and fund mobilization. This offers an opportunity to improve the capacity of national researchers, policy makers and practitioners (extension, education, development), to make use of research and to communicate its implications to policy makers. This, in turn, can make the tools available for wider application and testing, enabling the forward-looking scientific methods to inform and influence adaptation decisions.

Section 4. Results

This section provides an overview of the most important results in the A-Team countries arising from the project outputs and activities, and how the project advanced knowledge and practice on climate adaptation using the tools of RIA, RAPs and APs, with consideration of current and future opportunities. Significant effort focused on the methodology to identify and assess how decisions may evolve in the future. The creation of representative agricultural development pathways helps policy and decision-makers see how their plans may, or may not, respond to climate change, resulting in both anticipated and unanticipated learning during the research period, with findings also distilled and shared via the Impacts Explorer v2.0 for broader impact.

4.1 Ghana

Ghana's NAP targets the vulnerability of the agriculture sector to climate change and aims to determine appropriate adaptations to ensure farming systems are resilient to climate shocks. Policies at the national level intend beneficial outcomes at the local level, however, there are often gaps between the policies and implementation due to a number of issues such as changes in short term priorities, shifts in focus to other sectors with the potential to bring more immediate impact, inadequate funding to implement strategies, and inefficient or weak institutional coordination.

The type of policies a country has, and how they are implemented, will have an impact on the agricultural landscape in terms of its resilience to shocks - particularly those related to climate. Thus, with the support of a diverse group of stakeholders, three national RAPs were developed: the business as usual (BAU), sustainable development (SD) and fossil fuel driven development (FFD) pathways, as summarized below (further information on the national RAPs and how they link to the regional scale can also be found in Annex 13.2 (Info- and Policy-Briefs: Ghana, Senegal and Zimbabwe).

The BAU scenario is characterized as having generally good policies but weak institutional coordination that is limited by the tendency of funds to be redirected to address issues in other sectors. For example, funds earmarked for district assemblies to resource sectors at the local level are often used for other activities at the national level. There is also inconsistency in the enforcement of laws to ensure environmental sustainability, leading to the degradation of biodiversity, with implications for the natural resource base of farmers. Investments in infrastructure are also limited, with inadequate attention to gender equity. Thus, the system is bequeathed with low productivity, slow economic growth, poverty, and food insecurity.

The SD pathway also has good policies. In contrast to BAU, however, the implementation of policies is effective due to strong inter-institutional coordination and massive investments into environmentally friendly infrastructure as a result of private sector participation in development. Conservation of natural resources is key under this RAP. Gender equity and participation of stakeholders in decision making is at the core of the SD pathway, leading to improved productivity, gradual but sturdy economic growth, and reductions in poverty and food insecurity.

The FFD pathway is characterized by government policies created to entice private sector participation in infrastructure developments. The implementation of policies is effective owing to the participation of strong institutions and stakeholders in decision making and implementation. However, environmental sustainability is sacrificed for rapid economic growth. Still, poverty and food insecurity are expected to reduce, with improvements in gender and economic equity.

The identified parameters were quantified for each RAP and used as inputs to socioeconomic modeling of climate change impact and adaptation assessments (see also Table 4.1).

Adaptation Strategies

To reduce the effect of climate change on the households in the future (2030-2035), an adaptation package co-identified by stakeholders was tested for three simulated crops (maize, peanut and sorghum). The adaptation package was based on the adoption of improved heat tolerant seed varieties. To ensure that households can acquire these improve varieties, the seeds were subsidised. For the other non-simulated crops and livestock, the adaptation package was designed based on literature (see also Figure 4.1.1 and Table 4.1).

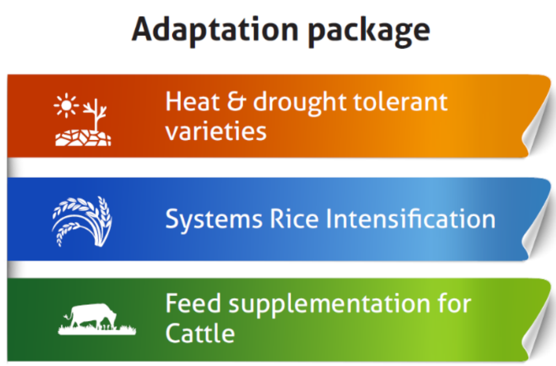


Figure 4.1.1: Stakeholder co-generated adaptation packages

Impact of RAPs on farmers' livelihood

The current production system in Navrongo is grossly under-optimized and, as a result, characterized by low productivity. The net farm returns of farmers in the future, under the plausible RAPs, are expected to be higher compared to model projections for the current production system. However, the magnitude of the improvements depends on the agricultural pathway that is pursued (e.g., see Figure 4.1.2).

The models project that net farm returns could potentially increase by about 100% under the SD and FFD pathways even though they are quantified differently across the RAPs. The increases in net farm returns for all the 3 RAPs are due to increases in investment in the farm input sectors (e.g., fertilizers, mechanization) that lead to increased uptake of those inputs as well as improvements in socio-economic and bio-physical factors like farm size, household sizes and projected commodity prices.

Table 4.1 Ghana parameters from RAPs and the Adaptation Package

	Business as Usual (BAU)		Sustainable Development (SD)		Fossil Fuel (FF)	
Productivity trends (%)	RAPS					
Maize	1.31		1.37		1.26	
Peanut	1.21		1.25		1.18	
Sorghum	1.43		1.48		1.38	
Millet	1.47		1.51		1.43	
Rice	1.36		1.39		1.33	
Vegetables	1.28		1.33		1.24	
Livestock	1.15		1.50		1.40	
Price trends (%)	*No CC*	*With CC*	*No CC*	*With CC*	*No CC*	*With CC*
Maize	1.21	1.24	1.25	1.29	1.19	1.26
Peanut	1.00	1.18	0.93	1.15	1.06	1.34
Sorghum	1.20	1.27	1.19	1.29	1.23	1.34
Millet	1.09	1.19	1.02	1.14	1.18	1.34
Rice	1.08	1.18	1.00	1.11	1.17	1.35
Vegetables	1.05	1.12	1.04	1.11	1.07	1.18
Livestock	1.10	1.11	1.15	1.16	1.06	1.07
	Maize-based farms	*Non-Maize-based farms*	*Maize-based farms*	*Non-Maize-based farms*	*Maize-based farms*	*Non-Maize-based farms*
Household (size)	7.06	6.33	7.53	6.75	6.59	5.90
Off-farm income ($)	877.91	759.79	1004.39	869.25	929.99	804.87
Farm size (ha)	3.23	3.18	3.49	3.45	3.76	3.71
Maize share (%)	16.48	NA	16.48	NA	16.48	NA
Peanut share (%)	19.96	12.83	19.96	12.83	19.96	12.83
Sorghum share (%)	25.47	30.74	25.47	30.74	25.47	30.74
Millet share (%)	20.65	33.15	20.65	33.15	20.65	33.15
Rice share (%)	17.43	23.28	17.43	23.28	17.43	23.28
Adaptation package						
	Maize-based farms	*Non-Maize-based farms*	*Maize-based farms*	*Non-Maize-based farms*	*Maize-based farms*	*Non-Maize-based farms*
Seed cost						
Maize	46.0526	NA	46.0526	NA	46.0526	NA
Peanut	87.3158	87.3158	87.3158	87.3158	87.3158	87.3158
Sorghum	22.1053	22.1053	22.1053	22.1053	22.1053	22.1053
Change in Producivity (relative yields)*						
Maize (% change yields)_APSIM	1.01-1.05 [1.03]	NA	1.03-1.04 [1.04]	NA	1.00-1.02 [1.01]	NA
Maize (% change yields)_DSSAT	1.05-1.09 [1.07]	NA	1.08-1.11 [1.10]	NA	1.02-1.13 [1.07]	NA
Peanut (% change yields)_APSIM	1.00-1.02 [1.01]	0.99-1.01 [1.00]	1.01-1.02 [1.01]	1.00-1.00 [1.00]	1.13-1.19 [1.19]	0.99-1.02 [1.00]
Peanut (% change yields)_DSSAT	1.11-1.19 [1.14]	1.10-1.21 [1.15]	1.08-1.10 [1.09]	1.07-1.10 [1.09]	1.00-1.01 [1.15]	1.12-1.22 [1.16]
Sorghum (% change yields)_APSIM	1.00-1.01 [1.00]	1.01-1.06 [1.02]	1.00-1.01 [1.00]	1.00-1.02 [1.01]	1.00-1.01 [1.00]	1.01-1.02 [1.01]
Sorghum (% change yields)_DSSAT	1.04-1.08 [1.05]	1.04-1.08 [1.05]	1.04-1.05 [1.04]	1.04-1.05 [1.04]	1.03-1.07 [1.05]	1.03-1.06 [1.05]
Millet (% change yields)	1.11	1.11	1.11	1.11	1.11	1.11
Rice (% Change in revenues)	1.49	1.49	1.49	1.49	1.49	1.49
Rice (% Change in variable cost)	1.03	1.03	1.03	1.03	1.03	1.03
Vegetables (% change in net returns)	1.28	1.28	1.28	1.28	1.28	1.28
Livestock (% change in revenues)	1.21	1.21	1.21	1.21	1.21	1.21
Livestock (% change in variable cost)	1.27	1.27	1.27	1.27	1.27	1.27

* relative yields are shown as ranges with the mean values in brackets [x]

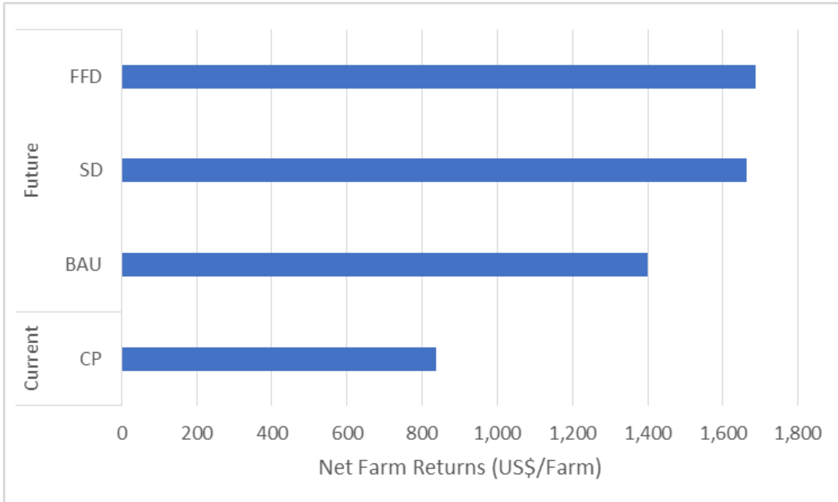


Figure 4.1.2: Impacts of agricultural development pathways on the income (net farm returns) of smallholder farmers in Navrongo, Ghana. CP, BAU, SD and FFD are current production system, business as usual, sustainable development and fossil fuel driven development pathways, respectively.

Increased net farm returns under future production systems translate into significant reductions in the proportion of farms that are food insecure in the current production system (82%) compared to those under the 3 RAPs; the SD pathway may result in larger improvement in food insecurity (32%) compared to a BAU (40%) but the FD pathway (29%) projects the greatest reduction. As with food insecurity, the proportion of farms below the poverty line declined from 68% in the current system to between 32 and 24% in the future under the RAPs.

Even though the projected improved livelihoods of farmers under the SD and FFD pathways appear similar in this analysis, we anticipate the FFD pathway suffers from greater environmental trade-offs - such as degradation of the natural resource base and potential increases in greenhouse gas (GHG) emissions - that were not captured in this study. Thus, the SD pathway is likely to be the more resilient pathway, contributing to SDG goals 1 (an end to poverty) and 13 (sufficient climate action). From this we conclude two important findings:

- Agricultural development can help to improve income, and reduce poverty and food insecurity, and hence improve the overall livelihood of farmers by the mid-2030s, especially under the SD pathway.
- When assessing benefits and trade-offs of multiple RAPs, it is important to also quantify resource or environmental degradation factors associated with the RAPs.

Impact of climate change on farmers' livelihoods

Overall, the magnitude of yield losses for cereals under climate change is larger for future production systems compared to the current system due to cereals' sensitivity to higher temperatures. The reduction in yield is least under the SD scenario due to the lower projected increase in temperature (GCM under RCP4.5, compared to the GCMs under RCP 8.5 for BAU and FFD). For peanut, all scenarios produce higher yield gains under climate change due to CO_2 fertilization effects (Figure 4.1.3). Lesser gains for FFD are due to the relatively poorer and shallower soils as a result of management practices that accelerate soil degradation.

The mean vulnerability of farmer households generally decreases in future production systems compared to the current system (i.e., plus signs within bars in Figure 4.1.4). In the future production system, vulnerability is least under the SD scenario and highest under the BAU scenario (Figures 4.1.4 and 4.1.5).

Socio-economic factors such as household size, farm size and other RAP elements, as well as projected prices of commodities under climate change, significantly reduced the negative impact of climate change on the livelihoods of farmers under the SD pathway. The net impact of climate change under the SD pathway is small but positive (with increases of 1- 6% in 8 out of 10 farms) whereas the net farm returns reduced in most instances under the BAU (with reductions of 1 – 11% in 6 out of 10 farms) and FFD (reductions of 2 – 9% in 5 out of 10 farms) scenarios.

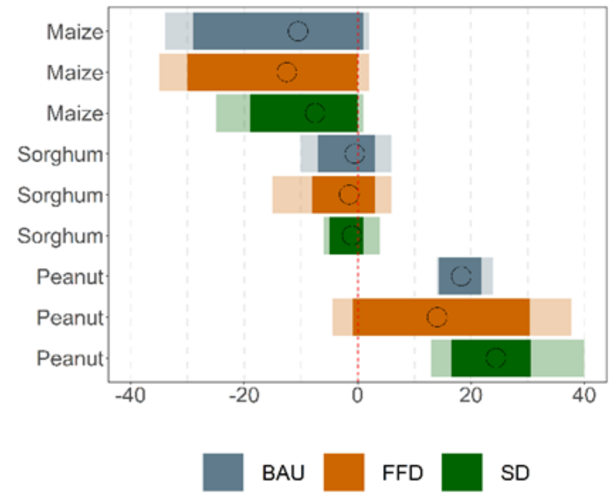


Figure 4.1.3: Climate change impact on crop (maize, sorghum and peanut) productivity in Navrongo, Ghana under different future agricultural pathways. Each bar represents a distribution of yield changes from 2 crop models and 5 climate scenarios.

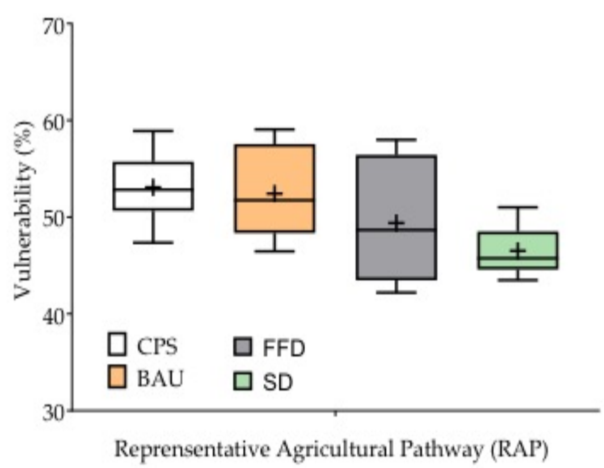


Figure 4.1.4: Impact of climate change on household vulnerability under current and future agricultural production systems. CPS, BAU, FFD and SD are current production system, business as usual, fossil fuel driven and sustainable development, respectively.

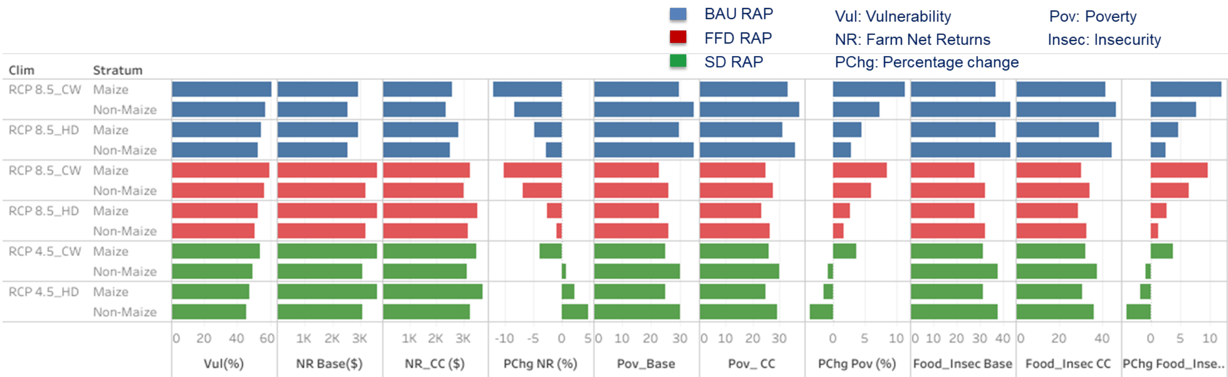


Figure 4.1.5: Impact of climate change on vulnerability, net farm returns, poverty, and food insecurity under future agricultural production systems. CW, HD, BAU, FFD and SD are cool/wet scenario, hot dry scenario, business as usual, fossil fuel driven and sustainable development, respectively.

Overall, poverty declines by up to 5% in most instances (with a possible increase of up to 1%) under the SD scenario while it increased for most farmers under the FFD and BAU scenarios by up to 7% and 10%, respectively (Figure 4.1.5). The trend of food insecurity is similar to that of poverty across the 3 development pathways. As with poverty, food insecurity reduced for 8 out of 10 farmers (1 – 6%) under the SD scenario while it increased 2 – 8% for BAU and 3 – 10% for FFD scenarios. Vulnerability under the BAU scenario was similar to that under current production system. In any case, vulnerability to climate change remains significant under the different pathways, which suggests the need to design adaptation strategies targeted at improving farm productivity, income and household livelihoods.

In summary, policies and interventions under the SD Pathway result in positive impacts of climate change compared to the BAU and FFS scenarios (i.e. farms become more resilient to climate change under the SD pathway).

Benefits of adaptation strategies in future production systems

The use of longer cycle cultivars resulted in higher gains in yield across all three crops simulated. The gain in yield is marginally higher for maize than for sorghum, perhaps owing to differences in heat stress susceptibility, which results in shorter crop life cycle with less grain yield. A longer life cycle produced higher yields for peanut than for the cereals (Figure 4.1.6), though there was no consistent pattern in yield gains across the scenarios.

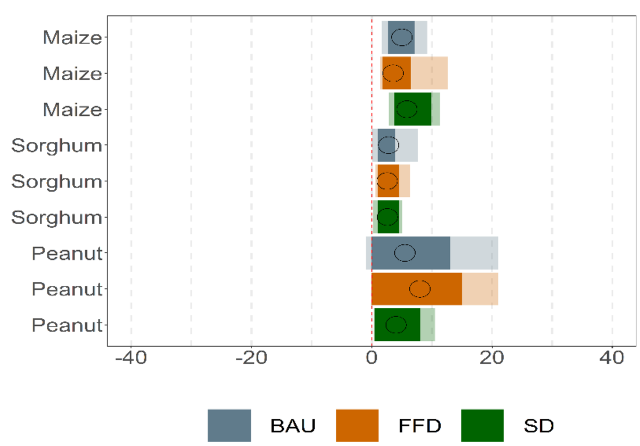


Figure 4.1.6: Impact of adaptation on crop productivity in Navrongo, Ghana under different future agricultural pathways. Each bar represents a distribution of yield changes from 2 crop models and 5 climate scenarios.

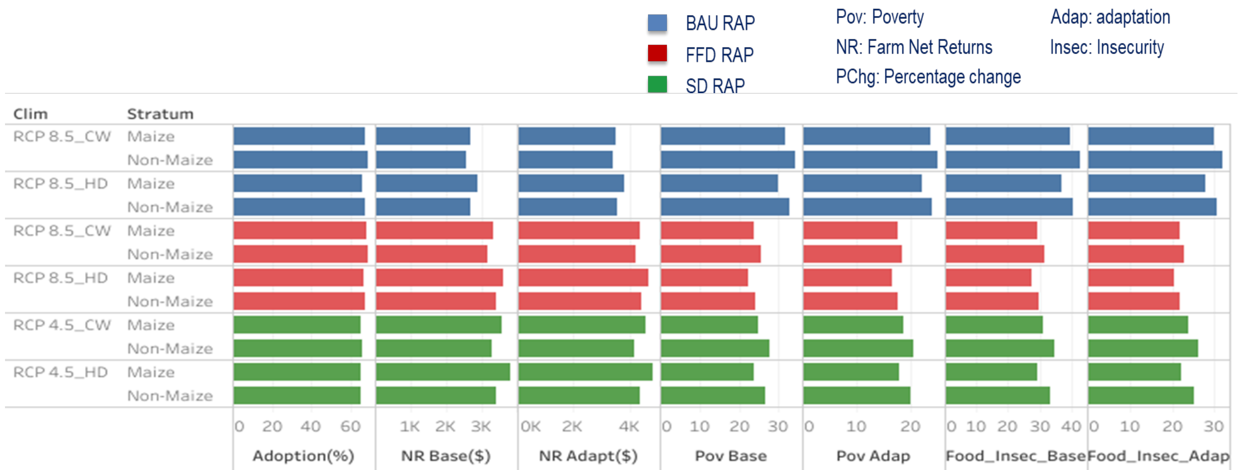


Figure 4.1.7: Impact of climate change on vulnerability, net farm returns, poverty, and food insecurity under future agricultural production systems. CW, HD, BAU, FFD and SD are cool/wet scenario, hot dry scenario, business as usual, fossil fuel driven and sustainable development, respectively.

The introduction of the adaptation strategies resulted in at least 60% of farmers adopting the package. The adoption leads to increased mean net farm returns (25, 27 and 29% for the SD, FFD and BAU scenarios respectively; see also Figure 4.1.7), resulting in a reduction in poverty and food insecurity. Development pathways and well-designed adaptation strategies can reduce food insecurity and help the country against hunger and improve nutrition.

The results in Figure 4.1.7 are stratified to compare how maize based households (strata 1) fared compared to non-maize based households (strata 2). Results are for two climate scenarios (cool wet and hot dry) that represent the two extremes for the study sites.

Adoption of the adaptation strategies resulted in a comparative increase in net farm returns and a reduction in poverty and food insecurity for both strata under SD and FFD scenarios, compared to the BAU scenario. Non-maize based systems experience lower net farm returns, and higher poverty and food insecurity. This result is somewhat surprising in light of the anticipated favorable outcomes anticipated with the incorporation of peanut. We anticipate that it may be owing to the focus on adaptation benefits absent sufficient consideration of their implied resource or environmental trade-offs.

Agricultural and climate change policies and interventions conducive to sustainable development and climate resilient agricultural systems can improve farmers' livelihoods, reduce poverty, and food insecurity. This, in turn, will help the country's fight against hunger, improve nutrition and enable movement towards achieving SDGs. Integrated forward looking assessments, which are stakeholder-driven and include multi-models (climate and crops) at multi-farms level provide evidence-based or science-based information for policy decision making, planning and priority setting.

Sustainable intensification of agriculture in the farming system, coupled with appropriate investments in climate smart agricultural infrastructure, is required to improve the livelihoods of smallholders in Navrongo and other farming systems or locations with similar characteristics as the farming system currently being optimised. Diversification of farming systems with more leguminous food crops will potentially improve the resilience of the farming system by improving soil fertility while benefiting from CO_2 fertilization, improving net farm returns and increasing overall livelihoods. In summary,

- High adoption rates of proposed adaptation strategy lead to an increase in farm net returns and a decline in poverty rate and food insecurity

Other important findings from the project

This project involved many hands-on exercises that generated productive brainstorming and discussion sessions. The varied backgrounds of the selected stakeholders enriched the discussions. Consensus building was also enhanced. However, the results also indicate that some important factors were not given sufficient weight in the climate change adaptation discourse. For example, it became evident through the stakeholder interactions that neither the socio-economic factors implied by RAPs, nor the effects of decisions on commodity prices, which are major determinants of climate change impact on livelihoods, had been fully addressed or understood in terms of its likely climate change impacts.

It also emerged that capacity in areas such as model use for agricultural decision making and policy formulation is grossly lacking, while also recognized as much needed, especially among the technical advisors to government ministries. Further, the project was intended to introduce forward-looking, integrated approaches (e.g., AgMIP RIA) as an additional method for assessing climate change impact. Stakeholders showed appreciation for this, although neither they nor their technical advisors can currently execute AgMIP protocols. The benefits of training have been repeatedly emphasized by stakeholders.

Never-the-less, the aims of the project were met. The project was intended to improve stakeholder knowledge in climate change and adaptation. This was largely achieved through the many hands-on exercises on scenario development. Furthermore, the concept of RAPs provides a basis for projecting future polices on climate change impact. The project was also intended to improve information dissemination via the production of policy briefs that convey climate change impacts to a more general non-technical audience. This has been largely achieved. However, the goal of impacting the actual process of policy formulation and planning by the government could not be fully achieved, though it is envisaged that this will be aided by the improvement of knowledge gained by stakeholders, especially from government ministries.

Though not initially intended, various ministries found the project output relevant and desire to host some of the results and outputs on their web pages. This shows the value and importance of this project to stakeholders.

Summary of Key Results for Ghana

- Research that links Ghana's national and regional policy development and implementation can better support climate change adaptation at each scale.
- Evidence-based research outputs can enhance policy decision making processes for more efficient and targeted investments with the implementation of climate change adaptation strategies.
- A robust adaptation planning system includes the assessment of environmental trade-offs implied by RAPs and APs, when establish best policies and technological interventions at farm and landscape scales for key agricultural production systems.
- Forward looking methods like the AgMIP RIA are essential to:
  - Inform policy and investment decisions on appropriate adaptation strategies.
  - Identify potential vulnerable groups under climate change.
  - Provide evidence for prioritization and budgeting for implementation.
- Capacity building in forward-looking methods and tools in Ghana's education and technology initiatives will strengthen national and local policymaking for better agricultural outcomes at a range of scales, even with changing climate.

4.2 Senegal

With Senegal aiming to be emergent by the mid-2030s, exploring different plausible trajectories of the agricultural sector is timely and relevant. The overarching goal is to establish future-looking policies at the national level that will continue to benefit agriculture at the regional level.

RAPs co-development with stakeholders (policy and decision-makers, farmers, scientists; see also Section 3.2) benefited from their different areas of knowledge and expertise. These sessions helped identify specific national policies and drivers influencing the agricultural sector for assessment of the direct and indirect effects of these national-level drivers in the future. In addition, working with stakeholders about plausible futures improved their interest and capacities in foresight analysis linked to impact assessment methods.

Despite the challenging conditions due to COVID-19, an iterative process based on workshop sessions and informal meetings with these stakeholders contributed to designing three RAPs: Business as usual (BAU), Sustainable development (SD), and Fossil fuel development (FD). Linking the national and the sub-national scales, we also assessed key implications of the national RAPs on regional RAPs.

The Business as Usual Pathway

The agricultural sector is characterized by the implementation of projects and programs aimed at increasing the productivity of the main agricultural sectors. These projects and programs do not include longer-term considerations. Agricultural growth is erratic, with disparities between regions, despite options aimed at sustainable productivity, increasing the income of rural households as well as the competitiveness of value chains of economic and social importance. Agricultural production is repeatedly subjected to recurrent problems of distribution of inputs and markets. The main value chains related to food crops do not benefit from sufficient budgetary resources, leading to increased production volatility. The low production capacity makes it challenging to significantly improve food and nutritional security objectives in a context of high population growth. Investments in the agricultural sector are concentrated on hydro-agricultural developments and the motorization of irrigated rice, tomato and onion crops. However, rainfed food crops (millet, sorghum, cowpea, maize) and groundnuts remain the key crops cultivated by the vast majority of farmers. The fight against poverty and socioeconomic inequalities is considered in social policies with special projects and programs emphasizing on the protection of the most vulnerable populations, particularly in agricultural and rural areas. However, the weakness of institutional capacities to effectively enforce reforms and the absence of a clear targeting of most vulnerable populations lead to low positive impacts of those programs and projects implemented, especially in education, training and public health.

The Sustainable Development Pathway

By 2035, the State is opting for a sustainable agriculture that preserves the environment by focusing on agroecological transition. Major reforestation programs and restoration of degraded land are implemented to increase the potential of cultivated areas. Production systems are supported by agricultural intensification measures, mainly through better targeting of fertilizer subsidies for small producers, especially organic ones, which increase agricultural yields. Access to credit, supported by the establishment of a rural sector development fund, is facilitated by interest rate subsidies targeting the poorest farmers. Production increases and provides more and more households with decent incomes. Land tenure regulation ensure the security of small family farms and provide better access for women to land and credit. The construction of road and product conservation infrastructures facilitates the integration of products into markets and reduces post-harvest losses. The shortening of distribution channels, through the establishment of producers' organizations and multi-stakeholder alliances in value chains, makes the prices of agroecological products competitive in comparison with conventional ones.

The Unsustainable Development Pathway

By 2035, the agricultural sector is experiencing fast economic growth supported by an agricultural policy whose main objective is to improve productivity to strengthen food and nutritional security, rebalance the trade balance and develop competitive integrated high value-added sectors. This agricultural policy is backed by significant public and private investment through a substantial agricultural subsidy for inputs (seeds and fertilizers) and an exemption or increased subsidy on agricultural equipment and materials. The intensification of agricultural production, water management through new irrigation systems, and the use of new technologies are all areas where research is making considerable progress in terms of innovation, particularly with the development of improved varieties, especially in cereals and vegetables. The massive use of chemical fertilizers and the overexploitation of natural resources are, however, leading to severe degradation of land, water, and forests. The scarcity of land resources leads to significant inequality of access at the expense of women and young people. Agribusiness is developing very rapidly to the detriment of family farming. Access to credit and banks is facilitated for producers and agricultural entrepreneurs through the funds injected into this sector. The extensive use of fossil fuels, chemicals and the overexploitation of other natural resources also leads to an increase in greenhouse gas emissions despite the various initiatives in favor of the environment. The parameters from RAPs and the Adaptation Package for Senegal are shown in Table 4.2.

Table 4.2. Senegal Parameters from RAPs and the Adaptation Package

	Business As Usual				Sustainable Development				Fossil Fuel			
Productivity trends -2035												
Maize	0.85				0.9				0.82			
Peanut	1.39				1.15				1.15			
Millet	0.93				0.95				0.91			
Livestock	0.88				0.88				0.88			
Price trends - 2035	*High Price*		*Low Price*		*High Price*		*Low Price*		*High Price*		*Low Price*	
	No CC	*With CC*	*No CC*	*With CC*	*No CC*	*With CC*	*No CC*	*With CC*	*No CC*	*With CC*	*No CC*	*With CC*
Maize	1.21	1.24	1.21	1.02	1.25	1.29	1.25	1.03	1.19	1.27	1.19	1.06
Peanut	0.73	0.97	0.73	1.24	0.68	0.88	0.68	1.31	0.78	1.07	0.78	1.37
Millet	1.09	1.19	1.09	1.08	1.02	1.14	1.02	1.12	1.18	1.34	1.18	1.13
Livestock	1.10	1.11	1.10	1.01	1.15	1.16	1.15	1.01	1.06	1.07	1.06	1.01
Household size	11.63	11.27	13.09	13.10	8.73	8.45	9.82	9.83	11.63	11.27	13.09	13.10
Off-farm income (USD)	1086.90	1041.61	1460.84	981.71	1086.90	1041.61	1460.84	981.71	1086.90	1041.61	1460.84	981.71
Land allocation	*Strata 1*	*Strata 2*	*Strata 3*	*Strata 4*	*Strata 1*	*Strata 2*	*Strata 3*	*Strata 4*	*Strata 1*	*Strata 2*	*Strata 3*	*Strata 4*
Farm size (ha)	7.47	7.16	8.64	8.64	9.95	9.55	11.52	11.52	6.64	6.36	7.68	7.68
Maize share (%)			15%	13%			15%	13%			15%	13%
Peanut share (%)	38%	39%	41%	42%	38%	39%	41%	42%	38%	39%	41%	42%
Millet share(%)	29%	27%	26%	27%	29%	27%	26%	27%	29%	27%	26%	27%
Other crops share (%)	33%	34%	33%	32%	33%	34%	33%	32%	33%	34%	33%	32%
Herd size (TLU)	3.0	1.4	9.6	3.4	1.6	0.8	5.1	1.8	3.0	1.4	9.6	3.4
Adaptation package - Relative change in crop yields and livestock revenues												
	Strata 1	Strata 2	Strata 3	Strata 4	Strata 1	Strata 2	Strata 3	Strata 4	Strata 1	Strata 2	Strata 3	Strata 4
Maize yields			1.08	1.1			1.13	1.16			1.07	1.08
Peanut yields	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03
Millet yields	1.05	1.13	1.14	1.14	0.95	0.95	1.12	1.13	1.15	1.13	1.15	1.14
Livestock revenue	2.8		2.8		2.8		2.8		2.8		2.8	

Strata 1: Farms with no maize with livestock. Strata 2: Farms with no maize and no livestock. Strata 3: Farms with maize and livestock. Strata 4: Farms with maize no livestock

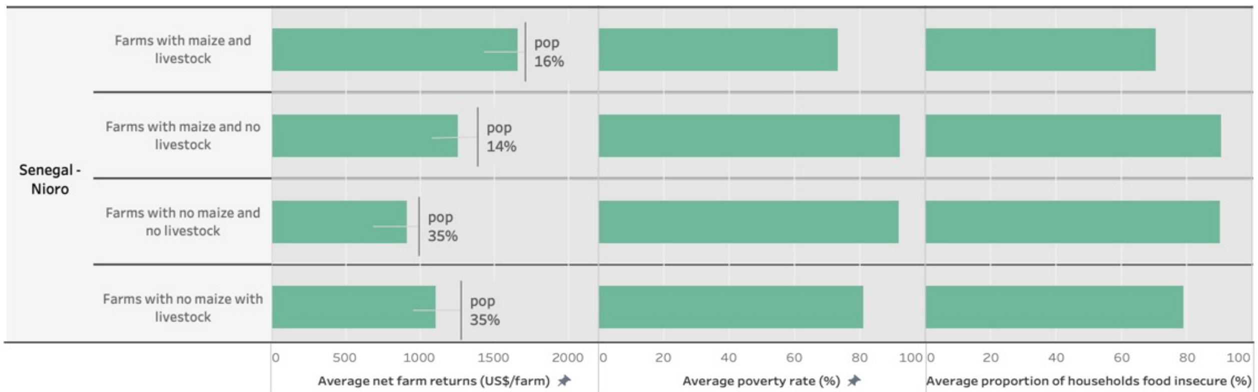


Figure 4.2.1. Current socio-economic conditions in Nioro, Senegal. Average net farm returns, poverty rates and food insecurity by stratum. The share of population in each stratum is shown next to net farm returns.

Current socio-economic conditions in Nioro, Senegal

Farming systems typical of this region are characterized by low productivity levels, low income and high poverty rates and food insecurity (Figure 4.2.1). Small farm sizes and large households contribute to this situation. Poverty rates between 65% to 92% demonstrate the already difficult situation under current conditions and no climate change. Food insecurity levels (i.e., the proportion of households that are food insecure) follows the same pattern as the poverty rates.

Adaptation Strategies

We defined an adaptation package based on the potential to increase crops yields and livestock revenues under future climate conditions changes and the policies or interventions that would enable the adoption of these adaptation strategies. The different components include genetic improvements on the cereal cultivars, a narrower planting window, and the improvement of management practices. The management practices increase the planting density, in combination with the application of more fertilizer, which is feasible due to interventions that improve farmers' access to fertilizers.

The second component in the adaptation package refers to investments in livestock to improve milk/meat production (with a particular emphasis on product quality enhancements) and herders' revenues. These investments include fodder banks to facilitate food availability for the cattle. In addition, we have services to improve pasture management along with improvements to market access.

Impacts of RAPs

Changes in average net farm returns from current conditions to future conditions (without climate change) are shown in Figure 4.3.2, together with projected poverty rates. All RAPs show improvement in net farm returns compared to current conditions. The SD pathway shows the greatest net farm returns, with projected increases as much as 300%, and associated large scale decreases in poverty rates. Even while all pathways will improve livelihoods, poverty rates remain high, especially under BAU and UD/FF scenarios.

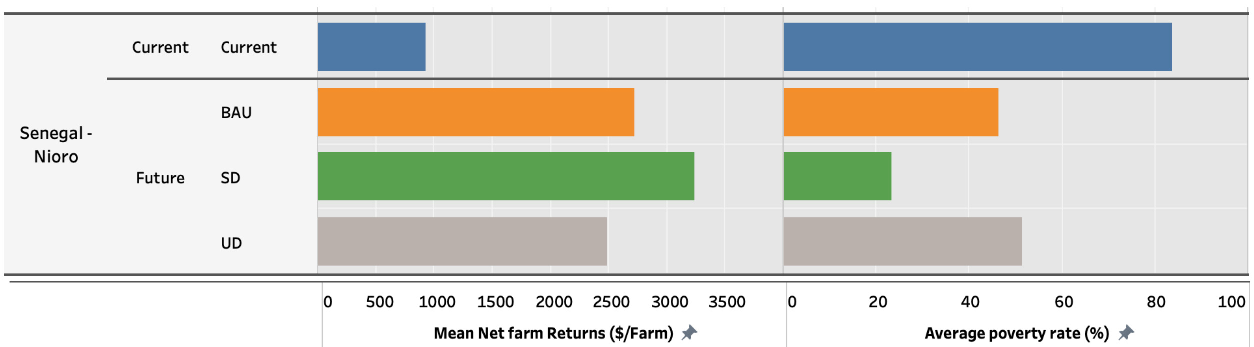


Figure 4.2.2. Agricultural development pathways: Population mean net farm returns (US$/farm) and poverty rate (%) under current and future conditions for each RAP for the high price scenario.

Impacts of climate change

The crop yield impacts from climate change are shown in Figure 4.2.3. The groundnut contribution to farm net returns is significant in the present as well as under climate change, dominating the results (i.e., the impacts of climate change on the other crops in the system are quite small by comparison; see also Figure 4.2.4, Current CC, Future CC). This results in increasing average net returns, and reductions in poverty, for all RAPs. Even under current conditions, climate change is projected to increase farm net returns because of groundnuts.

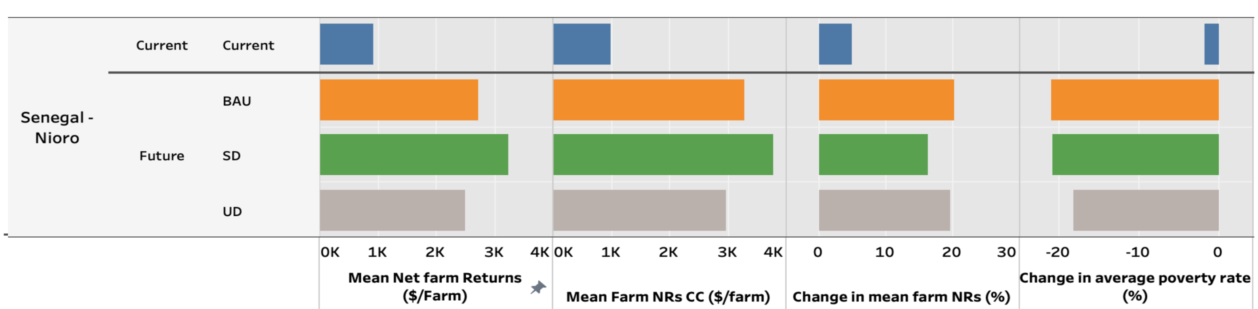


Figure 4.2.3. Climate change impacts on population mean net farm returns (US$/farm) and poverty rates for the combined farm systems of Nioro, Senegal.

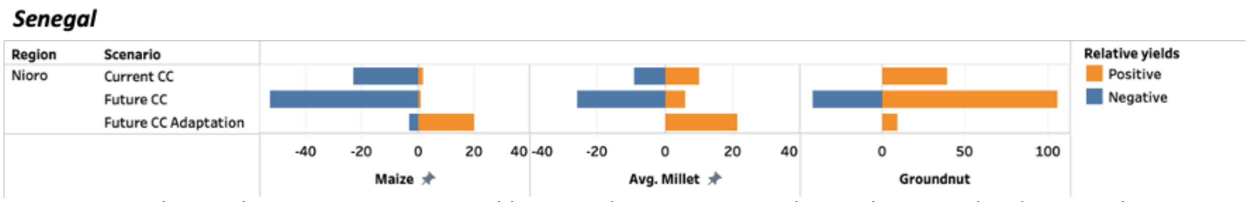


Figure 4.2.4. Climate Change Impacts on crop yields. Groundnut responses to climate change tend to dominate the system.

Impacts of Adaptation

The benefits of implementing the adaptation package under climate change for Nioro farm systems are shown in Figure 4.2.5 (see also Figure 4.24, Future CC Adaptation).

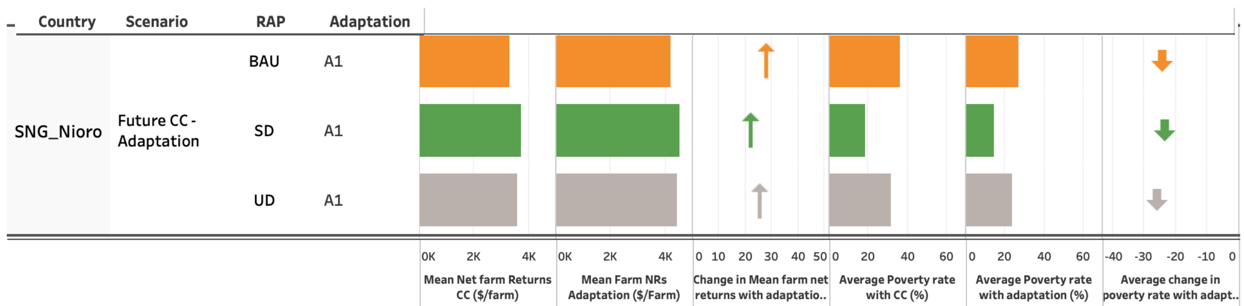


Figure 4.2.5. Benefits of adaptation packages under the three RAPs for each site.

Discussion

Model results show that future agricultural development leads to positive changes when comparing the current and future farming conditions with no climate change. Mean net farm returns are higher in each of the three different RAPs compared to current conditions. These positive findings are partly attributed to more investments targeting the agricultural sector (with different levels depending on the future pathway considered). Net returns can potentially double or even quadruple, depending on the pathway considered. However, SD was found to be the best in improving farmers' livelihoods. With SD, poverty could remain around 20%, whereas it could exceed 50% in UD. Food insecurity is also expected to decrease in all pathways, but more significantly with SD. From 80% of food insecure farmers today (i.e. farmers that can't afford a nutritionally adequate food basket), the percentage may range between 57% and 14% in the SD pathway, whereas the UD pathway ranges between 57% and 38% only. Thus, investing in better environmental and agricultural conditions for farmers will play an important role in improving farming systems and farmers' livelihoods sustainably. Farmers' future conditions may improve by the mid-2030s, especially if SD pathways are adopted.

In most cases, the results show that farmers may benefit from climate conditions in the future. Poverty decreases across the different pathways for most of the scenarios considered. This is mainly driven by the two aspects: crop prices increasing and increased yields of some crops with climate change. For example, groundnut (peanut) largely benefits from climate change due to CO_2 fertilization effects, with considerable yield increases. As peanut is an important crop in the region (the Groundnut Basin), the share of land allocated to peanuts in the Nioro farming systems is significant, contributing to positive net economic impacts, i.e. models predict more gains/gainers than losses/losers. Consequently, changes in farmers' net returns are positive in most climate scenarios and range between -3% and +24% in SD. Meanwhile, in the UD pathway, changes in farms net returns range between -43% and +34%.

In this analysis, we considered a range of climate scenarios, and in so doing, found that particular attention should be paid to the hot and dry climate scenario. Across all pathways, poverty tends to increase with this specific climate scenario. This is particularly true for unsustainable development, with poverty increasing up to 28%. Such a finding shows again how important it can be to enable conditions for sustainable development to ensure farmers' resilience to climate change. Climate change is likely to have positive impacts on reducing poverty, especially in the SD pathway.

Tackling the question on adaptation to climate change resulted in interesting insights in our model-based study. Farmers were projected to adopt the adaptation package as expected returns are higher with the adapted technology. This led to projected adoption rates ranging between 75% and 100%. As a result, net returns, when adopting the adaptation package, significantly improved farmers' livelihoods. The highest improvements resulted from farmers diversify their activities, including livestock, in a coordinated manner.

From top-down to bottom-up approaches in adaptation to climate change actions

There is often a discrepancy between policies shaped at the national level and their effectiveness once implemented at the local level. However, as adaptation is implemented on the ground, policy makers could be advised of challenges, resulting in adjustments to design. Inclusive policies with an emphasis on bottom-up approaches are necessary but suggest certain prerequisites. It is not necessary to have universal assessments, but there is need to generate accessible data and evidence specific to the key farming systems nationally, including with downscaled data of future climate projections. In addition, capacity building of local stakeholders remains a priority for the advancement of more localized adaptation plans and efforts, put forward for in conjunction with NAP processes.

Foresight analysis using Representative Agricultural Pathways

Emanating from the extensive support of stakeholders, the A-team co-designed three plausible trajectories of the agricultural sector by 2035: the BAU, the SD and the FD. SD is the most desired pathway based on stakeholders' consultations as it is based on the government vision

2030 policies and proposed interventions and investments. To take and stick to this path, a firm political will to advance and include policies that are sensitive to preserving natural resources is needed. Even though economic growth might be moderate in the short term, this pathway shows consistency and is likely to have enhanced resilience to shocks more generally. However, vulnerability to climate change remains important. For example, in the UD pathway, a hot and dry scenario may result in 3 out of 4 farmers becoming vulnerable. Such a situation requires more research to examine and identify interventions to decrease farmers' vulnerability to climate change.

4.3 Zimbabwe

The review of RAPs started by acknowledging that there is growing diligence in Zimbabwe towards climate change adaptation and mitigation planning in agriculture, supporting a national vision for agriculture and food systems transformation. However, there are gaps between national level agricultural and climate policies, science and policy making, and implementation at regional level. The AgMIP RIA methodologies illustrate what will be required to strengthen regional adaptations to climate change.

Currently, the particular conditions, needs and aspirations of agricultural systems in semi-arid areas, are not adequately addressed by agricultural and climate change policies and adaptation decision making. Challenges to adaptation in these high-risk areas are not sufficiently captured, documented, and reported, and as such, are yet to adequately inform planning and decision making at the national level. Without scientific evidence and bottom-up interaction, national policy and practice lacks sufficiently sensitive to the specific local requirements.

National Representative Agricultural Pathways

Three national Representative Agricultural Pathways (RAPs) were updated from the 2017 RAPs by the AgMIP CLARE scientists team, reviewed by technical experts and confirmed as plausible (Figure 4.3.1). They represent the BAU, SD, and UD scenarios, respectively. The RAPs help illustrate the characteristics and behaviours of the agricultural sector in Zimbabwe, from the current low agricultural productivity and high poverty levels into the future, and their responses to shocks, which depend on future drivers and conditions for implementing climate change adaptation. The RAPs show national agricultural and climate change drivers and policies, gender and inclusion policies under consideration, coherence in implementation, and the extent to which climate change adaptation supports sustainable and inclusive agricultural development.

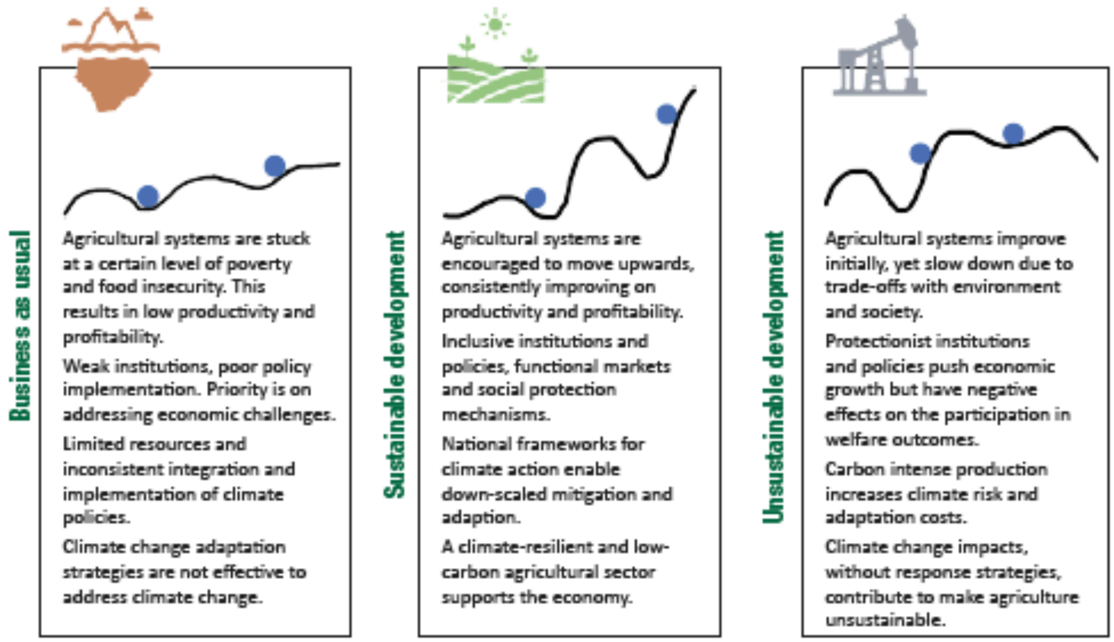


Figure 4.3.1. National Representative Agricultural Pathways (RAPs) in Zimbabwe, systems behaviour, drivers and outcomes (2030)

Regional Agricultural Representative Pathways and Adaptation Packages

Regional RAPs from 2017 were updated by the AgMIP A-Teams Project team for semi-arid areas using the Nkayi District as a case study (Figure 4.3.2). The regional RAPs incorporate the national RAPs as appropriate to regional conditions and preferences. As such, the agricultural interventions at the regional level are applied in consideration of gender and inclusiveness, or other regional priorities, as well as climate change adaptation.

The SD agricultural pathway develops and implements region-specific adaptation, gender and inclusiveness strategies, whereas the Unsustainable Development Pathway (UD) does not ascribe an importance to region specific climate change adaptation. Under the Business as Usual (BAU) pathway, region-specific climate policies might exist but are poorly implemented. Parameters from RAPs and APs are shown in Table 4.3.1.

Table 4.3.1. Parameters from RAPs and Adaptation Packages in Zimbabwe.

	Business-as-usual (BAU)			Sustainable development (SD)			Unsustainable development (UD)		
				RAPS					
Productivity trends (%)									
.Maize		2.08			2.26			2.08	
.Sorghum		1.51			1.62			1.51	
.Groundnuts		1.25			1.32			1.25	
.Cattle		1.45			1.55			1.45	
.Goats		1.04			1.13			1.04	
Price trends (%)	No CC		With CC	No CC		With CC	No CC		With CC
.Maize	1.19		1.26	1.25		1.29	1.19		1.26
.Sorghum	1.23		1.34	1.19		1.29	1.23		1.34
.Groundnuts	1.3		1.32	1.32		1.33	1.3		1.32
.Cattle	1.06		1.08/1.07	1.18/1.11		1.2/1.12	1.06		1.08/1.07
.Goats	1.06		1.07	1.19		1.2	1.06		1.07
Farm and HHs characteristics	0 cattle	1-8 cattle	> 8 cattle	0 cattle	1-8 cattle	> 8 cattle	0 cattle	1-8 cattle	> 8 cattle
Household size (persons)	1.05	1.05	1.05	1.1	1.1	1.1	1.1	0.9	0.9
Off-farm income (USD)	1.1	1.1	1.1	1.2	1.2	1.2	1.5	1.1	1.1
Farm size (ha)	1.2	1.2	1.2	1.2	1.4	1.4	0.6	1.8	1.8
Cropland allocation (%)									
.Maize	50	56	55	40	35	35	100	50	35
.Sorghum	32	28	30	10	15	15	0	0	15
.Groundnut	18	16	15	30	20	20	0	20	20
.Mucuna	0	0	0	20	30	30	0	30	30
Cattle herd size (TLU)	1	1.2	1.2	5*	1.6	1.6	1	1.8	1.8
Goat flock size (TLU)	1.2	1.2	1.2	2*	1.5	1.5	1.1	1.6	1.6
Cattle offttake (%)	5	5	5	20	20	20	20	20	20
Goat offttake (%)	5	5	5	20	20	20	20	20	20
				Adapation and mitigation packages					
A1. Change in crop varieties	Shift to drough tolerant varieties			Shift to drough tolerant varieties			Shift to drough tolerant varieties		
A2. Change in cropland allocation (%)				Crop diversification					
.Maize				18	18	18			
.Sorghum				18	18	18			
.Groundnut				25	25	25			
.Mucuna				17	17	17			
.Leucaena				22	22	22			
A3. Change in herd composition, offtake				Shift cattle to goats					
.Cattle herd size (TLU)				0.5*	0.5*	0.5**			
.Goat herd size (TLU)				1.5	1.5	1.5			
.Cattle offtake (%)				20	20	20			
.Goat offtake (%)				35	35	35			

Notes: HH=Household; TLU=Tropical Livestock Unit; Cattle = 1.14 TLU; goats and sheep = 0.11 TLU.

*Everyone who had no cattle or goats before would have at least five heads of cattle and/or five heads of goats

**Half the households convert all cattle to goats

Adaptation strategies were developed and tested under each RAP. SD addresses the need to prevent losses from climate change through down-scaled adaptation packages. The APs under BAU and UD were limited to switching to drought tolerant varieties, reflecting institutional limitations not attributing sufficient importance to climate change adaptation.

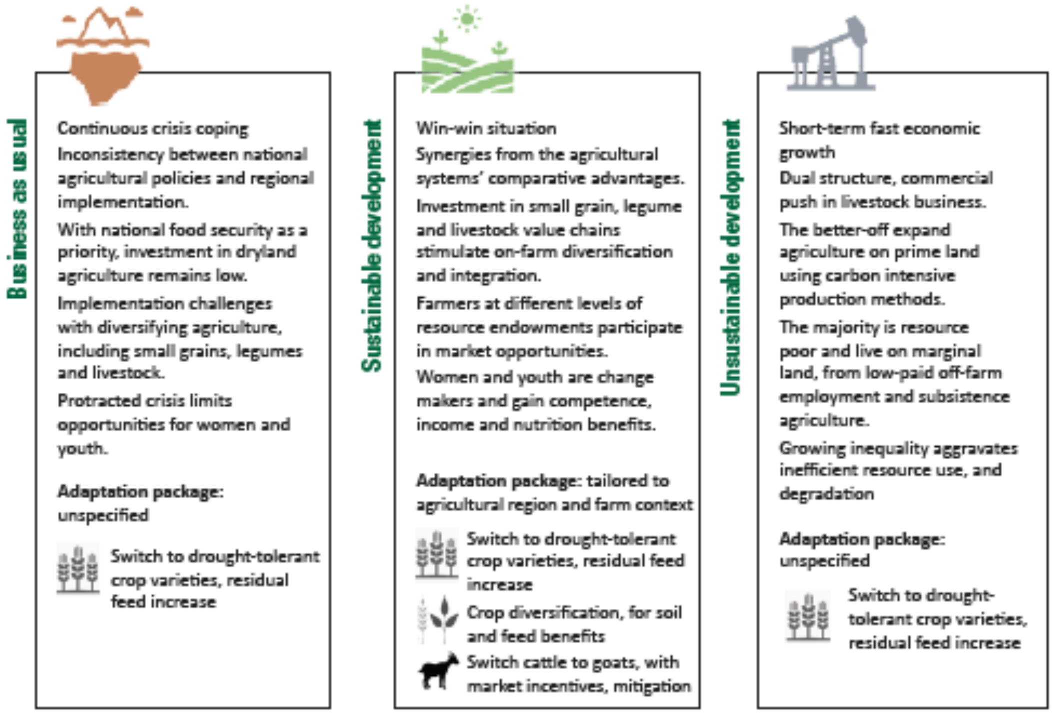


Figure 4.3.2. Regional Representative Agricultural Pathways (RAPs), mixed crop livestock systems, implementation and respective adaptation packages (2030)

Impact on crop and livestock production

We illustrate the range of future climate and adaptation impacts for hot wet (HW) and hot dry (HD) conditions, understanding that these are variations on a climate that tends to be hotter and drier overall. We differentiate the impacts for 3 sub-groups (strata) of farm households found in the Nkayi District: Extremely resource poor households (0 cattle, 42% of population studied), resource poor households (1-8 cattle, 36% of population studied), and non-resource poor households (>8 cattle, 12% of population studied).

In future agricultural systems, crop yields are generally higher than in current systems across all scenarios (Table 4.3.2). Yields are also higher on better quality soils as compared to poorer soils, under both climate scenarios, (HW and HD). Yields are higher under HW scenarios due to less water stress compared to HD conditions. The magnitude of climate change impacts is also larger. Maize yields are reduced owing to higher temperature effects on phenological development and grain filling, which is to shorten the time for nutritious biomass accumulation. Impacts on groundnut are mostly positive owing to the effects of CO_2 fertilization, which partially offsets the effects of increased temperature. Improved soils will be more important in the future for capitalizing on improved crop genetics and considering future climate factors such as rainfall and CO_2 for legumes in particular.

Table 4.3.2 Relative change in yields (%) for crop and livestock outputs, Nkayi District.

	Current		Future RAPs		Future Adapt	
	Lowest value	Highest value	Lowest value	Highest value	Lowest value	Highest value
Maize	-22	+22	-27	+6	-6	+15
Sorghum	-17	+9	-19	+10	-5	+13
Groundnut	+4	+42	-19	+30	+6	+20
Cattle offtake	-38	+10	-8	-1	-8	+1
Cattle milk	-30	9	-22	4	-12	+4

Livestock production in future systems increased, and was less sensitive to climate change, for both SD and UD, as farmers grew more fodder and fed concentrates to cattle to alleviate feed gaps, and thereby address livestock nutritional requirements for growth and reduced mortalities.

Impact on poverty

Under all future RAPs, farm households are better off than today. However, the main issue for mixed farming systems in Zimbabwe, regardless of climate change, is to look at improvements that would reduce poverty and inequality. Depending on which RAP followed, the levels of poverty are still significant and vary by farm type (Figure 4.3.3). This points to the need for social protection in future agricultural development strategies.

- SD is more effective in lowering poverty rates and provided greater equality by 2030, as agricultural incomes increase for all households, and poverty rates are reduced to 34%. Market and support services encouraged farmers to revise cropping strategies and increase land value by diversifying into more climate resilient and nutrient dense crops, prioritizing livestock for market functions. Livestock-based social protection packages were created for the resource poor so they could participate in the supply of livestock products; every household had at least 5 cattle.
- UD lowered poverty for those with livestock, but to a lesser extent than SD. Those with cattle increased herd sizes and prioritized high yielding crops using costly intensive production methods. An important issue with UD is inequality, as 85% of households are projected to remain poor, with the majority of households remaining dependent on subsistence maize production and low pay subsidiary off-farm income.
- BAU was less effective in reducing poverty, with about 65% continued to live below poverty line. Reducing poverty and food insecurity remained major issues.

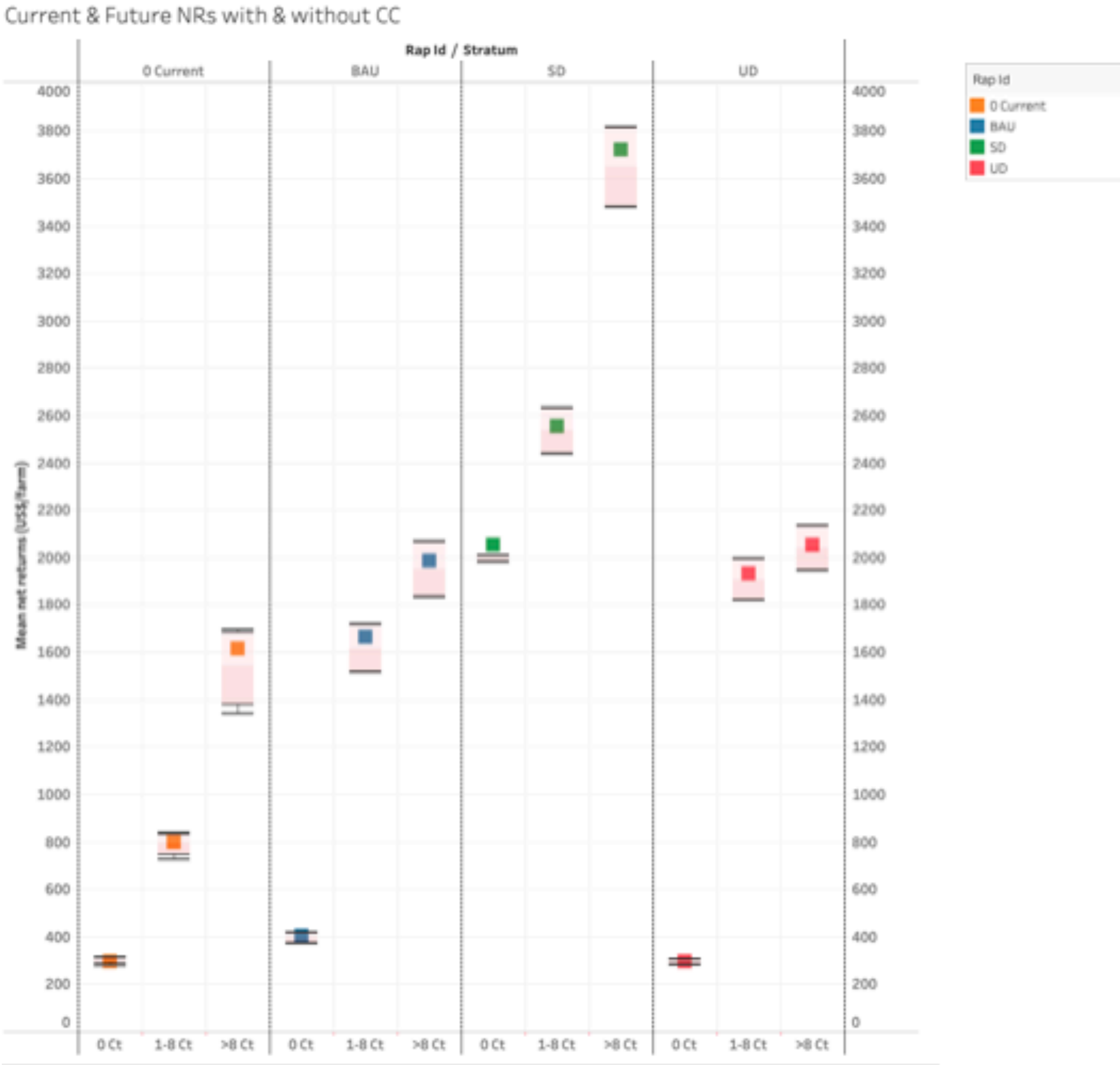


Figure 4.3.3. Impact of agricultural development and climate change for RAPs (BAU, SD, UD) and climate scenarios (Hot/Dry, Hot/Wet), and farm types in Nkayi, Zimbabwe, using APSIM and DSSAT results as input.

Vulnerability to climate change

Although the levels of agricultural production and income increased, many households remained vulnerable to climate change (47-60%). The impacts were felt more by those who had more land and larger cattle herds, as they lost more.

- SD off-set climate related losses more effectively. The resource poor households going into the future gained a lot from taking up cattle production. Even though they were more vulnerable, higher and more profitable agricultural production off-set the impacts of climate change.

- UD had high losses to climate change among those with livestock. The resource poor were less sensitive to climate impacts and lost less, as they were already impoverished and relied on small cultivated land and off-farm income.
- BAU had high losses to climate change particularly for those with livestock, due to feed gaps.

Impact of climate change adaptation

The high vulnerability at higher production levels illustrates that there is still need to design more appropriate climate change adaptation strategies to reduce losses and improve households' resilience to climate change, with a focus on specific resource endowments. The SD adaptations (3 sets; see also Table 4.3.3) provide larger benefits to farmers, accomplishing the goals of improving farmers' livelihoods and making the system more resilient to climate change, moving the system towards meeting the SDGs (Figure 4.3.4). The adaptation strategies

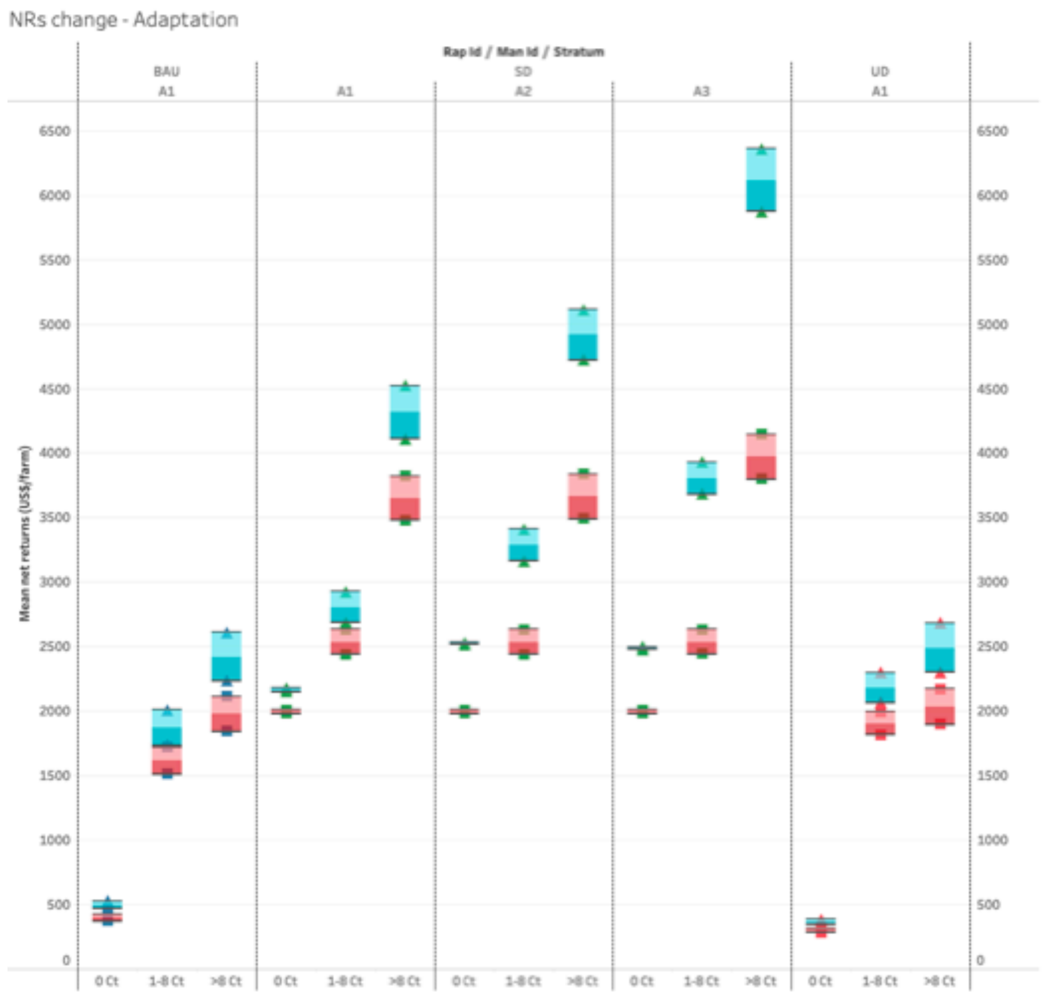


Figure 4.3.4. Impact of adaptation to climate change for RAPs (BAU, SD, UD) and climate scenarios (Hot/Dry, Hot/Wet), and farm types in Nkayi, Zimbabwe, using APSIM and DSSAT results as inputs.

Table 4.3.3. Sustainable Development Adaptation Packages

SD	A1	A2	A3
Adaptation Package	Drought tolerant varieties that perform well under higher temperatures.	A1, plus planting of high yielding fodder legume, *leucaena*.	A2, plus goats substituted for cattle (more resilient and easier for women to handle), with re-stocking cost sharing of 15%.
Adoption Rate	55%	84 to 86%	88-90%
Change in Farm Income	8 to 20%	28 to 32%	41 to 43%

implemented under BAU and UD provide small benefits for farmers with cattle. Resource-poor farmers without cattle do not see much in the way of improvements. Following the BAU or UD pathways would likely leave the resource-poor farmers behind.

The contribution of genetic crop improvement will be more effective if combined with (a) Improved soil fertility for higher yield response, and (b) Market improvements as incentives for farmers to purchase these varieties. Synergies with other management components will remain critical for increasing the returns on crop improvement. In contrast, with BAU or UD, the majority of farmers will continue operating on soils of poor fertility, making it more difficult to get out of that 'locked' state.

Implications for policy development

Further integrating science evidence into national and regional agricultural planning is critical for countries moving forward with climate change adaptation. National policies affect the way regional adaptation strategies are implemented, including how gender and inclusiveness strategies could develop. The intercomparisons of national drivers, regional implementations, and impacts thereof, can help with the design of effective adaptation strategies specific to particular agricultural systems and households, including for different levels of resource endowment and with gender inclusivity. Here we point out a few policy implications that this research has brought forward, that can help to address gaps in preparing agriculture sector strategies, specifically in semi-areas, to adapt to climate change:

- Supporting agricultural transformation: Transforming the agricultural systems starts with recognizing that poverty can be reduced, and farm household can become more food secure. This requires to shift the focus from narrow food security strategies (BAU), towards more complex pathways, with solutions appropriate for local conditions and farmer-focussed (SD).
- Strengthening resilience to climate change: Shifting the focus from crops to more diversified and integrated systems, with livestock as a main source of income, has been shown as effective and equitable poverty reduction strategy. There is need for transformative approaches that ensure the right conditions, as illustrated under SD. Efforts

in restoring soil productivity must be integrated with diversification into legumes and integration with livestock, to counteract climate change. Improved soils will be more important in the future for capitalizing on modified crop genetics and climate factors such as rainfall and CO_2.

- Linking agricultural activities to socio-economic development: In the semi-arid areas, climate change is not the main problem. Rather, it is having the majority of farmers being trapped on poor soils, with low input access and/or use and low levels of resource endowments. With high levels of labor migration this takes a toll especially on women. Climate change adaptation and mitigation in semi-arid areas can become easier in a context of functional value chains that support profitable uses of small grains, legumes and livestock, including incentives for farmers to adopt climate resilient and nutrient dense agricultural activities. There is need for women to play a key role as change makers, to ensure that value chains are inclusive and integrated with nutrition goals. Researchers and policy makers need to unpack root causes that restrict agriculture transformation to climate resilience and sustainability in semi-arid areas.

Updated, scalable national and regional RAPs and adaptation packages

The three national RAPs reflect major drivers, institutions, policies and technology, and the role of gender and inclusiveness frameworks. The regional RAPs illustrate to what extent national pathways support and respond to regional context specificity, and how they are being implemented. The intercomparative analyses inform what needs to be in place for moving from current conditions into a desired future and go ahead with climate change adaptation. They illustrate the importance attributed to climate policies and the consistency with downscaled adaptation and mitigation strategies, and challenges in regional implementation.

For the semi-arid region moving into the future, here represented through a case study in Nkayi District, following any of these pathways, the results illustrate that poverty levels were reduced. However, as the RAPs have illustrated, it is important to get agricultural policies right to support the transition to resilient and sustainable development and adaptation strategies by involving all actors.

- SD consistently implemented sustainability goals at national level and through downscaled strategies reduced poverty, malnutrition and inequality. Emphasis was on enhancing farm diversification and value chain development for commodities that are of comparative advantage. Inclusive gender responsive institutions and policies supported sustainable agricultural production systems to evolve.
- UD tied national interests and regional commercial business lines, but disregarded the implementation of environmental and social regulations.
- BAU national policies were not consistently implemented; extension, support and market structures were not effective in promoting diversification into dryland crops and livestock.

Adaptation strategies were developed and tested under each RAP, according to the importance that the RAPs attributed to climate action. SD addressed the need to prevent losses from climate change through down-scaled adaptation packages. The adaptation packages under BAU and UD were limited to switching to drought tolerant varieties, reflecting institutional limitations and not attributing importance to climate change adaptation.

Agro-ecological similarity scaling approach

The AgMIP project developed this approach (see also Section 5) to relate the regional and national scale conditions, to understand where recommendations from the RIA in a particular agricultural system like Nkayi District would matter. Maps, based on portfolios of observed and modeled layers illustrate similarities between regions in Zimbabwe based on climate, bio-physical and socio-economic characteristics. They can support adaptation decisions in Zimbabwe, as they illustrate areas similar in conditions and in the way they respond to climate. These need to be seen against the prevailing policies and other drivers, as elaborated through the RAPs.

The approach informs to what extent the point-based projections for an area like Nkayi District, representing prominent mixed crop livestock systems in Zimbabwe, could be transferred to other regions, and to what extend the recommendations are relevant at national scales. That can help to shape adaptation strategies, narrowing down particular adaptation skills and requirements.

Important key messages

1. There is heterogeneity in climate and agro-ecological conditions in Zimbabwe, which might limit the wide application of this analysis.
2. Current climate similarity: Areas from Northwest to Southeast seem currently similar and agro-ecological conditions and hence challenges to adaptation as Nkayi
3. Current agroecological similarity: Areas from North to South, slightly more in the west, experience similar climate change, which does not necessarily overlap with areas of currently similar climate
4. Climate change rate similarity: The central part of Zimbabwe seems to exhibit similar changes in climatic conditions as Nkayi
5. Future climate similarity: The central and northeastern part are projected to have similar climate in future as Nkayi
6. Current climates that are similar to projected Nkayi climate: Areas in the north west and north east are projected to be similar to current Nkayi climate, analogous adaptation strategies can be explored
7. Broad agro-ecology: Similarity is closest to Nkayi, and similarity is found in the Northeast and far western parts.

User stories

User stories provided insights on opportunities and linkages that emanated with partners through the engagement process.

- *Climate Change Management Department (CDMD) focal point* – The A-Team came in to address one of the main challenges to effective climate change adaptation in Zimbabwe. Evidence and information generated from the AgMIP A-Team Project is policy relevant and can feed into the on-going NAP and NDC processes, prioritizing climate smart agriculture as adaptation measure with mitigation co-benefits. The CCMD stands ready for facilitating demand driven research for development towards enhanced climate change adaptation and resilience. The findings of the project will also be used to inform the climate change adaptation project formulation as the country will be pursuing various climate finance facilities such as the Green Climate Fund and Adaptation Fund where CCMD is the Focal Point.
- *Lupane State University (LSU)* - During the AgMIP A-Teams Project, an opportunity to enhance the capacity of regional universities on forward looking research approaches arose. This would contribute to strengthen academic linkages to decision makers in strategic implementing organizations, such as development agencies and government departments (e.g. Meteorological Services Departments, Agricultural Extension, Development Agencies). This can help to infuse motivations for research-informed decisions through a wider network of actors into national policy decisions, supporting climate change adaptation. LSU introduced the AgMIP RIA approach as component in its MSc curriculum. Capacity development on simulation modeling supports a better understanding of vulnerability to climate change and adaptation strategies to contribute to sustainable agriculture.
- *Matopos Research Station (MRI)* - Research stations like MRI, under the Agricultural, Research, Innovation and Development directorate (formerly DRSS) link climate impact research with practical application and feedback to local level implementation through extension services. This provides opportunities for training, demonstrations and testing of adaptation technologies and interventions, and improved access to weather, climate and hydrological information under specific agricultural conditions. Site specific data collection can contribute to impact assessments for climate proofing technologies and interventions, under current climatic conditions and for projected climate change. As the host for regional Innovation Platforms that congregate relevant stakeholders, the stations are a strategic link for involving researchers, farmers, private sector, government and development organizations.
- *Climate science* - Experts agreed that Zimbabwe lacks the necessary capacity to access and analyse climate data, and technical equipment to objectively select appropriate climate models which assist in understanding the likely climate direction, and uncertainties related to climate modeling. AgMIP provides easy-to-use tools for future climate projections as well as R-programming scripts, which enable scientists to access and analyse future climate scenarios and climate projections. By making AgMIP methodologies, tools and data available to universities, researchers, young scientists and technical departments in

government, more work can be done to better understand the climate of Zimbabwe and to aid climate action, decision and policy-making.

- *Science communication* - The benefits of science research and effective policies are not widely understood in part because they are not well communicated. Science research and policy advocacy are technical and complex topics, but relevant and beneficial for development. The need for research outputs to be effectively communicated starts with multi-stakeholder consultations. Research processes must be collaborative and participatory. Researchers are knowledgeable in their area of expertise but there is a gap in terms of public understanding of their research outputs that the media could help fill. Promoting research/policy collaboration should include training the media on the workings of researchers and how policies are developed and adopted. This will foster the succinct articulation of the issues.

Section 5. Base Team Augmentations to Implementation

5.1 National Gridded Crop Modeling in Ghana

National maize production in Ghana is projected to decrease by the end of the mid-century (2035-2065) as compared to the average baseline (1980-2010) production level due to the effects of climate change. The magnitude of the decrease in maize production varies spatially (Figure 5.1.1 and 5.1.2). The largest impacts are projected to be in the central and southern region with more than a 35% decrease in maize production, and to a lesser extent in the northern region.

The projected climate scenario indicates a consistent increase in monthly average air temperature and a decrease in total annual rainfall compared to historical averages. As a result, the growing conditions are less than optimal for maize, causing heat and drought stress, which may explain the decrease in maize yield.

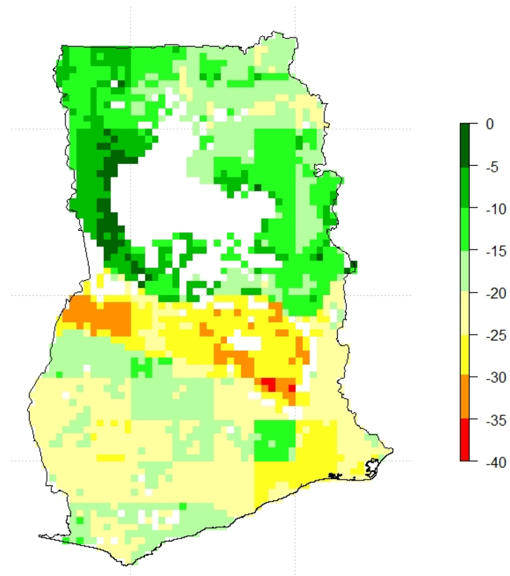


Figure. 5.1.1: Difference in maize production (%) from the baseline level.

Comparison of historical and projected climate scenario

We used the Geophysical Fluids Dynamics Laboratory's (GFDL) Earth System (ESM4) Global Climate Model (GCM) data for the historical (1980 - 2010) and future (2035 - 2065) climate

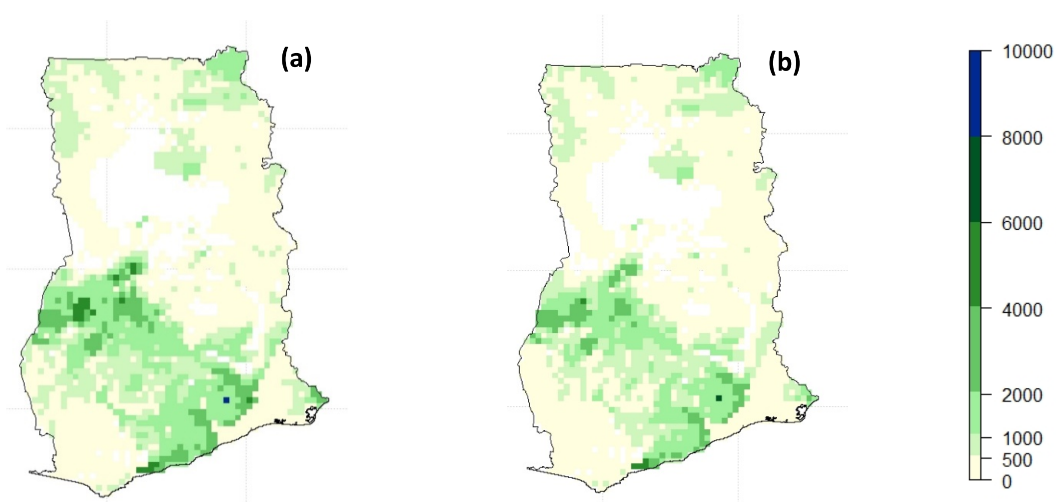


Figure 5.1.2. Average simulated maize production (in tons) for (a) the historical/baseline (1980-2010) and (b) for the projected climate data (2035-2065).

scenarios in these analyses. The future climate data were based on the Representative Concentration Pathway (RCP) 8.5 Socioeconomic Pathway (SSO) 5, high emission scenario.

Figure 5.1.3 shows the location of points analyzed in Figures 5.1.4 and 5.1.5. Compared to the historical average climate data, the projected climate data at the national level shows an increase in average air temperature (Figure 5.1.4) and an overall decrease in monthly total rainfall (Figure 5.1.5). The projected increase in temperature is up to 2.6 °C, especially during the months of November and December (Figure 5.4.4). The change in projected rainfall varies widely across the country and from month to month (Figure 5.1.5).

In the northern (S01, S02; Figures 5.1.4 and 5.1.5) and central sites (S06-S08; Figures 5.1.4 and 5.1.5) the projected decrease in rainfall occurs in August and September, while in the southern sites (S11, S12; Fig. 5.1.3 and 5.1.5) the projected decrease in rainfall occurs in May.

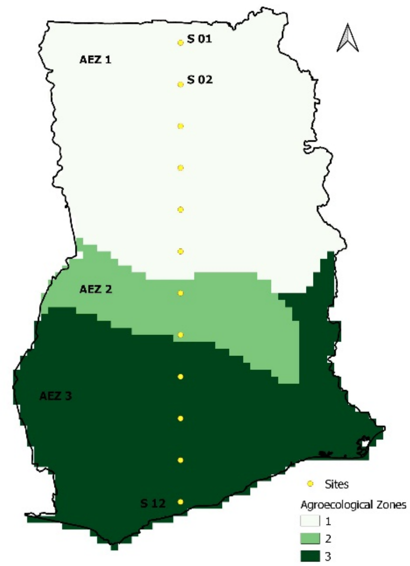


Figure 5.1.3: Agroecological zones and climate analysis points used in the study.

DSSAT-Pythia model inputs and simulations

The Decision Support System for Agrotechnology Transfer (DSSAT, dssat.net) is a crop modeling system for the dynamic simulation of crop growth and development, and estimation of crop yield. We developed a gridded modeling framework, called Pythia, to use DSSAT at multiple spatial scales. In this case study, we applied DSSAT- Pythia to simulate the potential impact of climate change on maize production system at the national scale in Ghana.

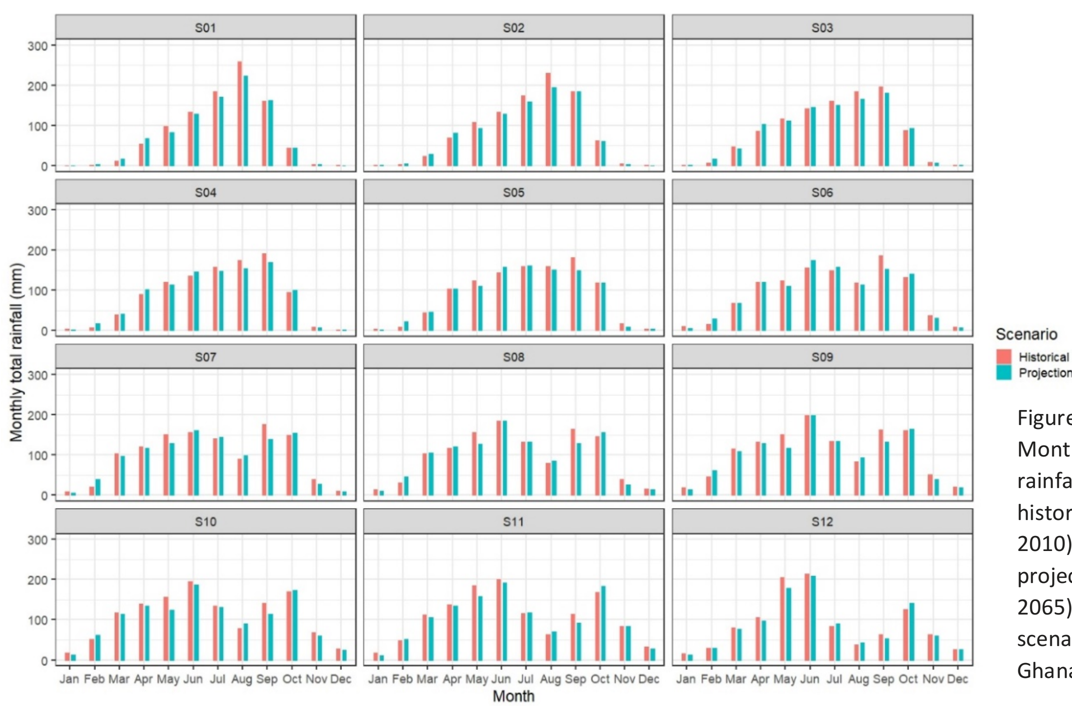


Figure 5.1.5: Monthly total rainfall for the historical (1980-2010) and projected (2035-2065) climate scenario for Ghana.

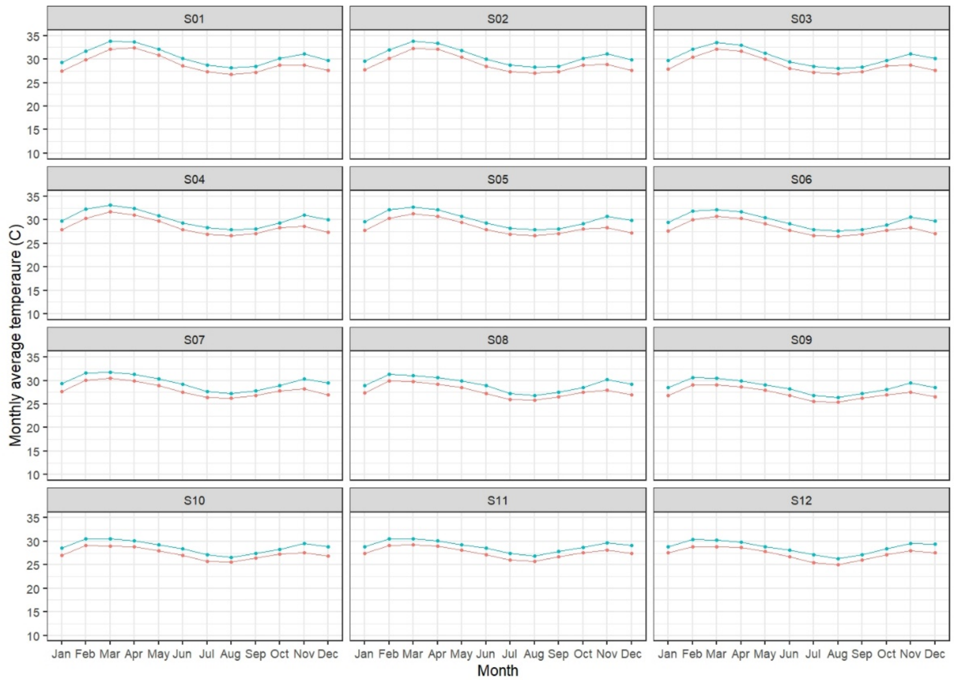


Figure 5.1.4. Monthly average air temperature for the historical (1980-2010) and projected (2035-2065) climate scenario for Ghana

The DSSAT cropping system model requires input data of daily weather conditions (maximum and minimum air temperature, solar radiation, and rainfall), soil profile information on physical and chemical properties, detailed crop management practices, and information on local cultivars. Spatial application of DSSAT at a national scale was conducted using Pythia. The weather data were obtained from the Inter-Sectoral Model Intercomparison

Project (ISIMIP) for the GCM GFDL ESM4, whereas the soil profile data were obtained from the combination of data from the International Soil Reference and Information Centre (ISRIC) and International Food Policy Research Institute (IFPRI). The weather and soil data were set up in grids at the resolution of 5 arc minutes and simulations were run at each grid using Pythia. Only those grids that are within the maize growing areas were considered for model runs. The maize production areas in Ghana were obtained from the Spatial Production Allocation Model (SPAM, 2010) maps provided by the IFPRI.

The SPAM maps provide maize harvest areas under three management systems, namely, high inputs, low inputs, and subsistence. We set up our crop management inputs for DSSAT, such as N fertilizer amount (high inputs-100 kg N/ha; low inputs-50 kg N/ha; and subsistence- 0 kg N/ha) according to the SPAM management system. Data on crop management practices, such as planting window, were based on the agro-ecological zones (Table 5.1.1 and Fig. 5.1.4). An improved maize hybrid, Obatanpa, was used for the simulation for all three agro-ecological zones.

Table 5.1.1. Planting window used for different agro-ecological zone in Ghana for DSSAT maize simulation.

Agro-ecological zone (AEZ)	Planting window
AEZ 1	June 1 to June 30
AEZ 2	March 20 to April 30
AEZ 3	April 15 to May 15

DSSAT-Pythia model simulation outputs

DSSAT-Pythia simulated maize yield (in blue color) closely follows the FAO reported annual yield (in orange color, linearly detrended to remove the effects of technology) for Ghana (Figure 5.1.6).

Historical/baseline maize production estimates (Figure 5.1.2a) were calculated from the sum of harvest area (from the 2010 SPAM maps) multiplied by the DSSAT-Pythia simulated yield for each pixel. The value for each pixel was then averaged over the 30 years runs. Production estimates for the future climate projection (Figure 5.1.2b) were calculated in a similar way, assuming no changes to land allocation. The darker green pixels indicate areas with high maize production whereas the light-yellow pixels indicate the region with lower maize production values (Figure 5.1.2).

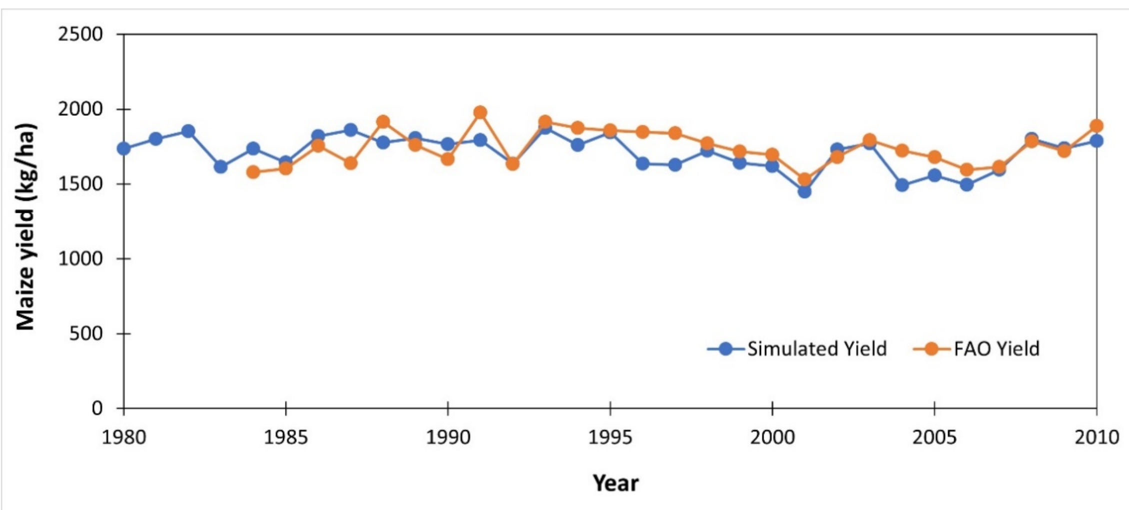


Figure 5.1.6: DSSAT-Pythia simulated maize yield comparison with FAO reported annual national maize yield of Ghana.

5.2 Linking Regional and National Scale Economics Methodologies in Senegal

The framework for Integrated National and Regional Assessments (INaRA; see also Section 5.7) outlines conventions in which model-based assessments can interact with each other, by using common assumptions and sharing results, to permit coordinated and consistent scenario analyses. National economic models are used to assess market and socio-economic effects of different risks, or policy actions. In the INaRA framework, they are used to simulate the effect of climate adaptation policies on the national agricultural commodity market, and are linked to global economic models, national RAPs, crop simulation models, and the AgMIP Impacts Explorer.

To test integration between different components of INaRA, the results from a regional RAPs process were used as scenario inputs to a national economic model, illustrated in Figure 5.2.1. Specifically, the TOA results for Nioro, with respect to the impact of climate on future agricultural systems, were used as inputs to IMPACT-SIMM, a nationally or regionally focused version of IFPRI's IMPACT model (Robinson, et al., 2015), which was, in this case, configured as a nationally-focused agricultural market model of Senegal.

There are several points of entry in which the assumptions, results, and policy variables of other models may be changed in IMPACT-SIMM. These include assumptions of macroeconomic trends, such as per capita income, explicit policy variables, such as taxes and subsidies, or results from other models following their own scenarios, such as crop area or yield growth.

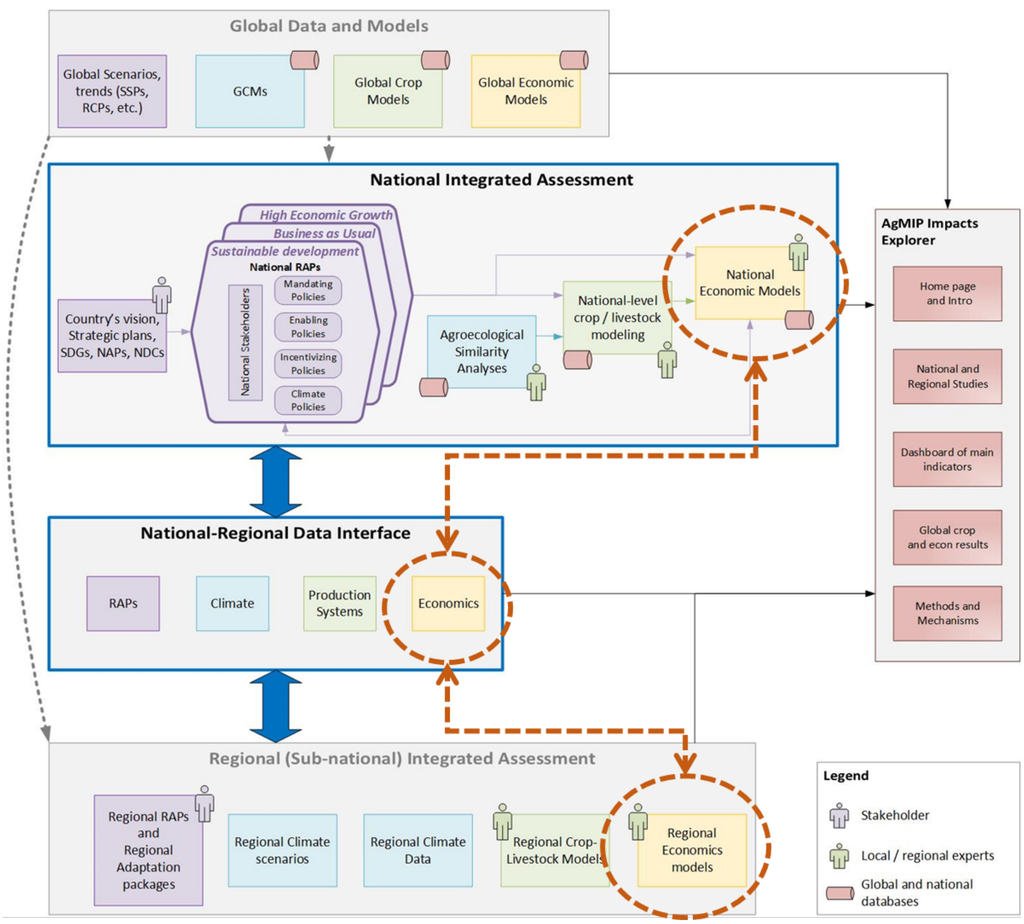


Figure 5.2.1. Linking results of regional economics models to national economics models via the national-regional data interface

TOA modelling for Senegal includes 40 scenarios of alternative combinations of RAPs, crop modelling results, and climate scenarios. Results are passed to IMPACT-SIMM via Excel spreadsheets, in which per capita income and crop production results for three key commodities, are available. Additional assumptions, including on import tariffs, and investment, are provided.

The crop production results were used to adjust baseline yield assumptions in IMPACT-SIMM to match production estimates from TOA, on rainfed maize and millet. The results for all other crops are unchanged from IMPACT-SIMM results, which are derived from results from the global IMPACT model. IMPACT-SIMM results are then used as inputs for the national RAPs. Results for variables of interest, including solution yield and areas, total production and trade, and consumer and producer prices, are recorded in separate data files, which can be passed back to the national or regional RAPs to refine the design of adaptation packages in an iterative process.

The exercise is a first attempt at soft-linking the results of one INaRA component to another, and reflects a promising test case for further integration of other components. Having been drawn from a global IMPACT model used to inform the initial TOA modelling as well, the national IMPACT-SIMM models offers a complete baseline from which to scenarios. Thus, if adaptation scenarios focus on only on a few crops of interest, no additional assumptions need to be made on the remaining commodities. Further, the identification of similar variables offers points in which different models can be linked. The use of Excel or CSV-based datasets also provides a useful, common format for sharing results.

Several lessons learned were also drawn to improve coordination across modelling efforts. These include:

Harmonization of geographical areas of interest: The Nioro region is the area of interest in the TOA modelling, while IMPACT-SIMM uses larger geographical areas defined by water basins within national boundaries. Potential linkages with crop models, which use higher spatial resolution, also present a challenge in which regions covered are not consistent. Thus, results need to be suitably aggregated to ensure an appropriate representation of regional characteristics in national modelling efforts.

Policy shocks need to be clearly identified and agreed across modelling groups: In addition to modelling results, a wider range of specific policy details should be shared across modelling efforts. These include the duration and pace over which a policy is implemented and, where applicable, whether the adaptation is likely to influence an input price, land availability, or crop yield.

Challenges in matching results: The number of variables for which consistency should be achieved across modelling efforts should focus on what is meaningful for the policies being tested. In many modelling systems, differences in how models are specified, as well as interaction effects, can make it difficult for one model to replicate the results of another, particularly when many endogenous variables are targeted. Some model results in TOA could not be suitably matched by IMPACT-SIMM. This is a useful result, though, as it offers insights from both models, on what may be driving or constraining production in each, potentially revealing where assumptions or policy design may be unrealistic.

The results show that improved coordination necessarily requires communication across modelling streams on specific details beyond the sharing of numerical results and assumptions, and offer some lessons for subsequent integration exercises. Next steps should seek to seek consistency across a larger set of assumptions and variables, encouraging discussion where extreme outcomes of one model can influence the results of other models to which it is linked. As more data are shared between modelling streams, another focus should be on automating the presentation and format of results in existing interfaces.

5.3 Agroclimatic Similarity Studies in Zimbabwe

Motivation

Earlier AgMIP integrated assessments focused on sub-national regions (on the scale of a district or network of neighboring villages) in order to characterize farming systems, climate hazards, agricultural vulnerabilities and opportunities for adaptation (Rosenzweig et al., 2015; 2020). These regions were selected according to their prominence as agricultural production areas, representative farming systems, engagement with local stakeholders and the availability of climate, crop, livestock and economic data. Results in these sub-national regions proved useful in assessing climate risk and the potential for a number of adaptation options; however, uncertainty concerning the extent to which these results could be transferred to other regions/systems or scaled up to national scales limited the overall utility of these findings for broader climate resilience planning. This project therefore explored a number of approaches to relate local and national scale conditions in order to understand where findings and key messages would likely be transferable.

Approach

Similarity between regional systems can be characterized by a combination of climatic conditions, biophysical conditions on the farm, and socioeconomics. Further distinction could be determined by similarity today (i.e., under present climate and farm systems) and similarity in the future (i.e., under future climate and farm systems). Here we demonstrate agroclimatic similarity analyses over the Zimbabwe component of the AgMIP A-Teams Project, focusing on the Nkayi district and household survey that was the focus of previous analyses and connecting into ongoing efforts within the country to update agro-ecological zones (AEZ) for the first time since the 1960s. Similar analyses were initiated in Ghana and Senegal as a proof of transferable approaches, but these are not the focus of discussion here.

The core approach develops a portfolio of observational and modeled layers that characterize one aspect of farm conditions across Zimbabwe (climate, crop, livestock, and economics; today and in future), determines conditions in Nkayi for that layer, establishes a range of conditions considered "similar" to the Nkayi condition for each layer, then identifies other regions in Zimbabwe that are within this range and therefore similar to Nkayi and likely to face similar challenges and opportunities to the farm households studied there. Details of the specific biophysical, current climate (focusing on the maize-growing season), future climate (under a high-emissions [RCP8.5] scenario for mid-century [2040-2070] conditions), climate change (future compared to present), and socioeconomic layers are provided in Annex 13.4, detailing each variable layer name, unit, spatial resolution, temporal resolution, time period, Nkayi value, Nkayi "similarity" range, and data description. Layers include biophysical information from satellite vegetation indices (such as the Enhanced Vegetation Index; EVI), land variables (including soil moisture and established agro-ecological zones, AEZ, updated in 2020 by the Zimbabwe National Geospatial and Space Agency), climate variables including average growing season conditions (e.g., temperature, precipitation), the frequency of extreme climate events (e.g., days where temperatures exceed 35°C), and socioeconomic conditions (e.g., livelihood zones and cattle density). As climate challenges reflect both difficult conditions as well as the rate of change that forces responses, climate conditions are given for current climate, future climate, and the amount of climate change.

Similarity ranges for quantitative variables were determined by first calculating the average of the values for the 7 villages included in the Nkayi farm survey. A first guess of ±10% set the range of similarity, with each layer further examined to ensure that this range of similarity helped distinguish conditions across Zimbabwe (that is, a layer where the whole country is considered "similar" does not add distinguishing regional information). Combinations of layers were then used to provide similarity "scores" for each part of Zimbabwe that reflect the number of layers within a given set that are similar to Nkayi. These scores are not weighted toward any individual layers other than in the selection of the inclusive set, so the analysis below forms a starting point for deeper analysis depending on the specific interventions that may target hazard resilience in vulnerable communities.

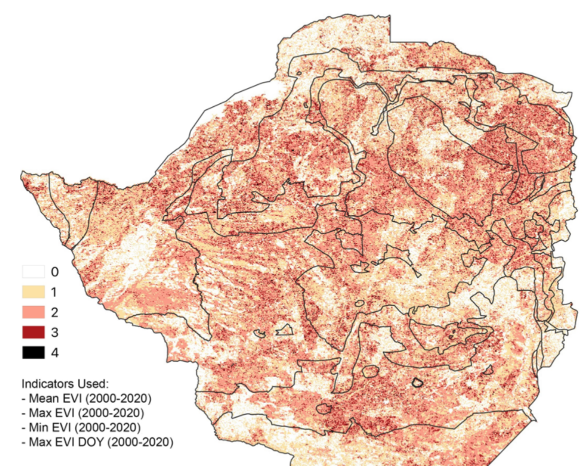


Figure 5.3.1: Current biophysical similarity score calculated from 4 similarity layers drawn from the 2000-2020 period: mean EVI, annual maximum EVI, annual minimum EVI, and the day of the year on which maximum EVI is observed.

Key findings

No single combination of layers (e.g., Figure 5.3.1) is sufficient to capture the many differences in Zimbabwe's diverse landscape, so we examine a variety of layer combinations to provide multiple perspectives on the common challenges and unique characteristics of agroclimatic conditions.

Current biophysical similarity: Figure 5.3.1 highlights areas within Zimbabwe that have a similar seasonal progression of vegetation to that observed in Nkayi. The average EVI describes the overall level of vegetation, which is a proxy for overall productivity and potential fodder for livestock. Maximum and minimum EVI values describe the annual amount of vegetation growth and dieback that highlights the best conditions and the lean months, while the day of the year for maximum EVI pins the vegetation growth to major seasonal patterns of temperature and rainfall that could distinguish different regional climates. Put together as a similarity score, there is no clear regional pattern of EVI characteristics that distinguish different portions of Zimbabwe, indicating that the overall vegetation pattern is quite similar across the country. Within each region there is strong heterogeneity, however, indicating sharp patterns in land management and contrasts between agricultural lands and unmanaged lands that could be natural or utilized for grazing.

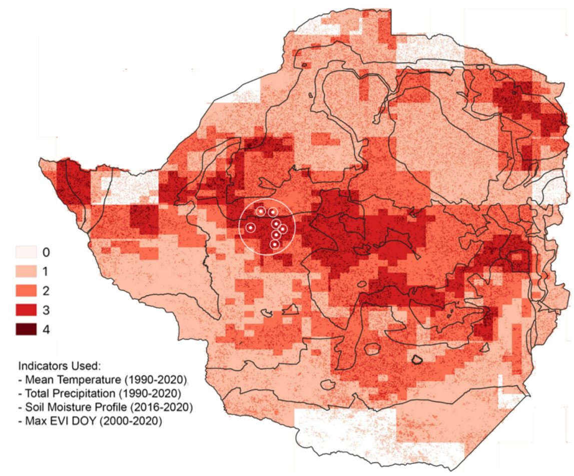


Figure 5.3.2: Current climate similarity score calculated from 4 similarity layers drawn from the 1990-2020 period: mean temperature, total precipitation, the number of extreme heat days (Tmax > 35℃), and the number of rainy days (P>1mm). The locations of the 7 surveyed Nkayi villages are shown as white circles within the broader Nkayi region.

Current climate similarity: The mean and extreme characteristics of Nkayi climate is similar to a broad swath across the center of Zimbabwe, as well as portions of the Northeast (Figure 5.3.2). The southernmost portions of the country share few characteristics with Nkayi climate.

Current agroclimatic similarity: The combination of core climate variables, soil moisture, and vegetation seasonal cycle reveals a slight Northwest to Southeast swath of the country that is similar to Nkayi (Figure 5.3.3). In contrast to the climate-only similarity that was oriented in a more West-

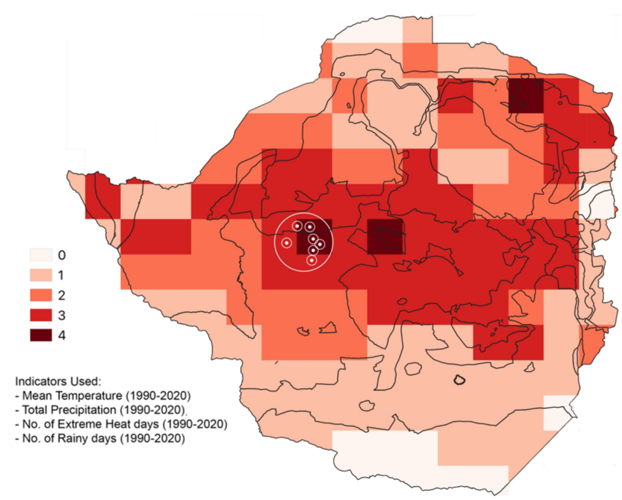


Figure 5.3.3: Current agroclimatic similarity score calculated from 4 similarity layers drawn from recent observations: mean temperature, total precipitation, soil moisture profile saturation, and day of year for maximum EVI. The locations of the 7 surveyed Nkayi villages are shown as white circles within the broader Nkayi region.

East pattern, interactions with soil conditions and vegetation show that regions along this more diagonal axis are likely to have similar conditions for agriculture. Comparisons against the livelihoods zone layer (ZINGSA, 2020) indicate that many of the zones that are highly similar to Nkayi on this combination of layers are also areas with prominent smallholder agriculture and mixed cereal-livestock systems. These zones are most likely to face challenges to agricultural adaptation and resilience planning that were extensively explored at Nkayi. Note that the resolution of the EVI seasonality layer is finer than the other layers, with many pixels similar across all 4 layers even as the other layers set the broader patterns.

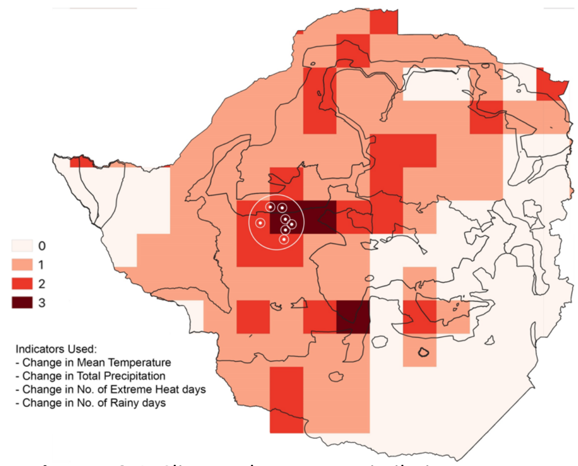


Figure 5.3.4: Climate change rate similarity score calculated from 4 similarity layers calculated as the difference between future (RCP8.5 2040-2070) and current (1990-2020) periods: change in mean temperature, change in total precipitation, change in the number of extreme heat days (Tmax > 35℃), and change in the number of rainy days (P>1mm). The locations of the 7 surveyed Nkayi villages are shown as white circles within the broader Nkayi region.

Climate change rate similarity: The rate of climate change experienced provides another perspective on adaptation and resilience planning similarity across regions within Zimbabwe (Figure 5.3.4) Climate change in Nkayi is projected to be similar to that of a North to South swath of Zimbabwe across the slightly more Western portion of the country. These regions may not have the same future conditions but are facing a similar degree of disruption in terms of climate changes. The pattern of changes for lower emissions scenarios (RCP4.5) examined in this study are similar even as the extent of climate change is reduced.

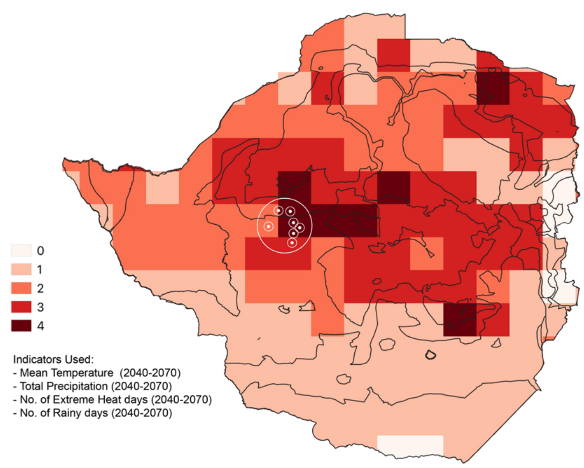


Figure 5.3.5: Future climate similarity score calculated from 4 similarity layers drawn from the RCP8.5 2040-2070 period: mean temperature, total precipitation, the number of extreme heat days (Tmax > 35℃), and the number of rainy days (P>1mm). The locations of the 7 surveyed Nkayi villages are shown as white circles within the broader Nkayi region.

Future climate similarity: In the RCP8.5 mid-century (2040-2070) period Nkayi will continue to have a climate similar to the central part of the country, although it will be increasingly similar to the Northwestern portions of Zimbabwe (Figure 5.3.5). In this sense adaptation and resilience planning actions between these regions will likely converge to reflect common conditions and climate challenges for agriculture.

Current climates that are similar to projected Nkayi climate: A comparison between Nkayi's future climate and the present climate of Zimbabwe shows that future conditions in Nkayi will be similar to conditions currently experienced in the northern portions of Zimbabwe, particularly those areas in the Northwest and Northeast (Figure 5.3.6). Adaptation and resilience planners in Nkayi might therefore look to present systems and climate risk planning in these portions of the country to anticipate solutions for their future challenges.

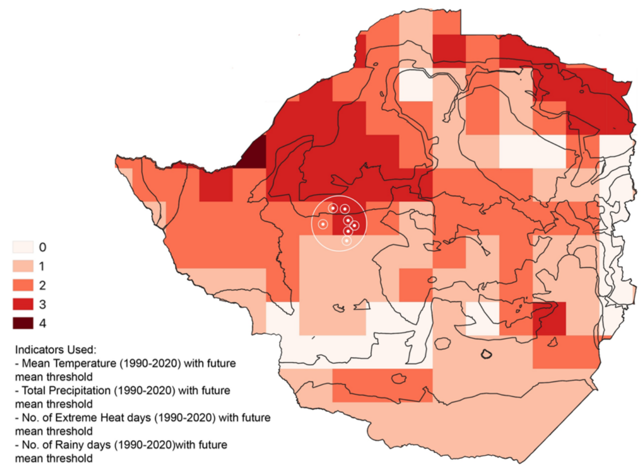


Figure 5.3.6: Current climates that are similar to Nkayi's future climate; thresholds drawn from Nkayi's future climate projection and applied to current climate layers. Similarity score calculated from 4 similarity layers drawn from the 1990-2020 period: mean temperature, total precipitation, the number of extreme heat days (Tmax > 35C), and the number of rainy days (P>0.1mm). The locations of the 7 surveyed Nkayi villages are shown as white circles within the broader Nkayi region.

Broad agro-climatic similarity: Figure 5.3.7 utilizes a broad set of biophysical, land, current climate and socioeconomic layers to identify regions that have strong acro-climatic similarity to Nkayi. The use of this many layers is instructive, but further analysis is needed to examine the specific combinations of similar layers for any given pixel. Overall similarity is strongest in the regions closest to the Nkayi farms and generally is reduced with distance, however higher similarity scores extend East into the center of the country and are also seen in the Northeast (between Mutoko and Mount Darwin) and far Western portions of Zimbabwe (southwest of Victoria Falls). Southernmost regions (near Beitbridge) and the Eastern area around Nyanga National Park are least similar, and therefore are not likely to be suitable for the adaptation and resilience planning efforts developed for Nkayi.

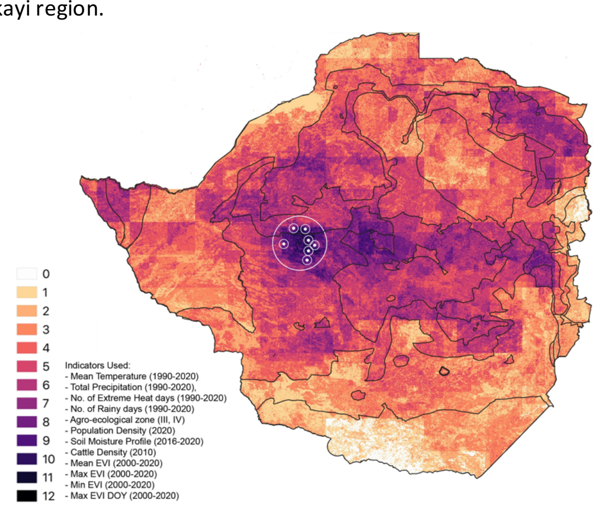


Figure 5.3.7: Broad agro-climatic similarity score calculated from 12 similarity layers drawn from recent observational periods: mean temperature, total precipitation, the number of extreme heat days (Tmax > 35℃), the number of rainy days (P>1mm), Agro-ecological zone, population density, soil moisture profile saturation, cattle density, mean EVI, annual maximum EVI, annual minimum EVI, and day of year for the maximum EVI. The locations of the 7 surveyed Nkayi villages are shown as white circles within the broader Nkayi region.

Opportunities for further application

Agroclimatic similarity analysis for Zimbabwe shows that adaptation and resilience challenges fall along geographical patterns that may be useful in efficiently transferring successful approaches from Nkayi to the broader country. In many cases Nkayi results are broadly applicable, but analysis indicates that there are not clear and coherent regions with identical conditions given the heterogeneity of climate and agricultural conditions within Zimbabwe. Other portions of Zimbabwe (or other count ries) may be more broadly representative than Nkayi, and this type of analysis may identify wide areas where adaptation and resilience planning may be useful in less heterogeneous countries. Preliminary explorations of this approach in Ghana, for example, show strong zonal bands associated with the Savanah, Sahel, and tropical forest portions of the country, while Senegal analyses indicate strong coastal and inland patterns.

The current approach can also be improved by better connecting the range of “similar” conditions to specific agricultural vulnerability and adaptation and resilience plan tolerances. For example, in the above analyses areas were considered similar to Nkayi if their total maize growing season precipitation was within 10% of the Nkayi value; however, additional information about farm system tolerances could more accurately set the range of plausible values for a given adaptation option and thus be more useful for planning. Continued engagement with local experts would also help identify additional layers and similarity thresholds that reflect the decision processes of stakeholders within the region (e.g., which seeds to plant, where to invest in livestock, whether irrigation is practical). Specific policies could also be targeted to a designed set of conditions that could be explored through geospatial analysis of these layers, either through a combined score based on custom ranges or on a multi-layer set of criteria to identify minimal conditions indicative of success.

Agroclimatic similarity analysis could also be combined with gridded crop modeling efforts (such as those piloted in Ghana) and national economic modeling (such as that piloted in Senegal) to build more efficient modeling systems that prioritize diverse systems or those with the highest economic impact or population vulnerabilities. Improved information about specific policies, adaptation investments, farm system transformations, and crop system responses to climate changes may also be factored into future analyses to inform more useful planning efforts.

5.4 Impacts Explorer

The A-Teams Project included three main activities to increase the Impacts Explorer’s impact and to ensure an improved resource for stakeholder exploration and co-learning. These are: (a) adding selected RIA results; (b) expanding the relevance of the AgMIP Impacts Explorer to global users and enhance the ability of in-region stakeholders to place their challenges in the global context through the addition of critical global data sets from AgMIP modeling activities; (c) improving Impacts Explorer user experiences, including through the development of an adaptation support pages.

To achieve these goals, a new design of the Impacts Explorer has been developed. The redesign was based on results of an extensive user requirements analysis including evaluation of the feedback on the previous Impacts Explorer (https://agmip-ie.wenr.wur.nl/, (implemented in AgMIP DFID); meetings with the A-teams to discuss the target audience for the CLARE project results and the formats for presentation; an interview with M. Leone, as representative of funding organizations; and the results of the baseline stakeholder interview and surveys; especially the section on the information sources used by national stakeholders.

The structure of parts of the current Impacts Explorer was reorganized to be recognizable as a support tool that includes information on current *and future* outcomes. The new setup and design were based on a review of existing climate change adaptation support tools and past experiences from WUR in developing such tools. New sections were added for the new national and regional assessments, global maps, and testimonials of stakeholders. The designs and prototypes were presented in several AgMIP A-Team Project meetings and feedback was used to adjust the design, to support the presentation of the national and regional assessments. Templates were created for the A-teams, to help structure and describe the results of the regional studies and regional and national assessments. For specific topics, such as the RAPs, diagrams were designed together with the A-teams and revised several times, for use in presentations as well as the Impacts Explorer. After consultation with the A-teams a map viewer has been developed to provide access to the maps at national scale.

Screenshots of Landing (below) and Methods (right) pages of the prototype Impacts Explorer v2.0

Screenshot of Linked *Regional* and *National* Adaptation information from the prototype Impacts Explorer v2.0

The Impacts Explorer v2.0 includes a section with Global Maps Viewers including maps produced by the AgMIP GGCMI Project and Maps based on the IFPRI IMPACT Model. For the design and implementation of the viewing tools, there have been deliberations with members of the GGCMI team and with experts from IFPRI.

5.5 Baseline Interviews and Surveys

The coordination team and the A-Teams in Ghana, Senegal, and Zimbabwe conducted interviews and surveys with stakeholders at the beginning of the AgMIP A-Teams Project to serve two objectives.

The first objective is to document what scientific analysis and information would assist stakeholders in advancing national climate change planning processes and adaptation in the agricultural sector in each country in order to inform the outputs that the AgMIP A-Teams Project should produce. The analysis of interview and survey data helped to design outputs that may serve stakeholders' needs and support national climate change planning.

The second objective is to advance the evaluation of the contribution that AgMIP A-Teams Project and broader AgMIP research is making to national climate change planning and adaptation in the agricultural sectors in the three countries. The findings from the interview and survey data inform the Theory of Change for climate change planning in each country and provide a baseline that documents national climate change planning processes, what information they use, and any role that past AgMIP research has played, at the beginning of the project. Evaluation will compare future outcomes to this baseline.

Interviews

Semi-structured interviews with 10 stakeholders who participate in the national climate change planning processes for agriculture in each of the three study countries provide the qualitative information about the progress in national climate change planning for agriculture; challenges; key decision makers and their roles; data, research, and information on which climate change planning relies; and needs for new data, research, and information. The stakeholders whom we interviewed represent a range of institutions and roles in national planning, including leading government ministries, other government ministries and departments, coalitions, development and technical partners, and researchers.

The research teams in each country identified respondents for the interviews based on institutional mapping. The interview guides contained the same questions in each country. We audio-recorded the interviews and transcribed the audio recordings. We analyzed the transcripts by identifying the main themes that emerged under each category of questions. We organized quotes from the transcripts by the themes, which they illustrate, focusing on points that were mentioned by three or more respondents in each country. Further details are available in the mid-project report provided in Annex 13.3.1.

Surveys

The sample for the baseline survey in each country comes from all stakeholders in the agricultural sector, a broader set than participants in the planning processes. The sample is not random. The sample includes researchers and decision makers identified by the research teams and additional individuals identified through a snowball sampling process, in which stakeholders who participated in interviews and other interactions suggested other important decision makers. We designed survey questions and answer options based on information collected through interviews. The survey questions in the were the same in each country. There were some differences between answer options that were relevant in each country. We analyze the percentage of respondents who selected each response or category of responses.

Key results

These below results informed the AgMIP A-Teams Project approach described in this report.

- **Summary of achievements and challenges in national planning processes**: The national climate change planning processes are in early stages in each of the study countries and challenges remain. However, important progress has also been made. Awareness of climate change and vulnerabilities of the agricultural sector to climate variability and change has increased in all three countries in recent years, especially at the national level, but understanding is still limited and is especially low at the local level. Each country has an institutionalized, consultative planning process, in which a national government ministry has the mandate to set priorities, guide, develop, and approve planning processes, policies, and strategic documents. The commitment to climate change planning and endorsement for climate change and adaptation projects in agriculture from national ministries have increased, but are not yet sufficient.

  Each country has developed a number of climate change and adaptation planning frameworks, including ones that address action in the agricultural sector in particular, for example advancing Climate Smart Agriculture (CSA). The policy and strategic documents are important not only because they set out national priorities, helping to guide planning and implementation, but also because stakeholders from national and local government, research, civil society organizations, development partners, and UN and international organizations have come together to form coalitions and platforms that have contributed to the planning documents and these new networks continue to advance progress.

  The creation of partnerships, collaborations, and coalitions has been an important success of the planning processes. These bring expertise from different technical areas and levels of society into the planning and implementation process, share information, and help to coordinate efforts. Coordination is important in order to use scarce resources efficiently.

Interview respondents emphasize that more collaboration and coordination is still needed. Climate change action in each country still suffers from projects that undertake the same efforts without being aware of each other, missing opportunities to increase scale and failing to build on lessons learned. Competition over roles and mandates sometimes impedes progress.

All three countries have established relationships with international development and technical partners, and have made progress in attracting funding for climate change work. However, capacity to effectively utilize available funding and technical capacity to develop bankable projects with a strong climate rationale continues to be a significant constraint. Interviewees report limited capacity to write proposals that attract funding.

Major obstacles to progress are formulation of national policy that does not adequately reflect differences in challenges and conditions across the country, insufficient communication between local and national levels, as well as inadequate knowledge and capacity at local level to engage in climate change planning, to influence planning at the national level, and to implement adaptation strategies. Study respondents emphasize that many decisions about managing climate change and implementing adaptations are made at the local level, by local government, civil society organizations, farmers, processors, distributors, and households. Local experiences and solutions rarely filter into national policy-making, and without this bottom-up interaction, national policy and practice is not adequately sensitive to local circumstances.

Research has contributed to the successes in climate change planning and action in the three study countries. Research has developed the climate projections and understanding of vulnerabilities that have focused attention and generated commitment to action on climate change. It has informed the national documents. Research organizations have joined partnerships and coalitions and exercise influence through their technical expertise. Research is also key to funding. For example, the GCF, which is a major source of funding for work on climate change and adaptation, requires that proposals show that the problems being addressed are caused by climate change. More generally, proposals are more likely to be successful when they are based on credible evidence. However, much remains to be done.

- **How research can contribute to building national planning capacity**: Many interviewees mention that information needed to guide risk management and adaptation decisions in specific contexts in the countries is scarce. Information is typically aggregated at a global level or for supra-national regions. Climatology, climate projections, vulnerabilities, and adaptation options at aggregated levels may not be appropriate for guiding decisions that are made primarily at local levels given that adaptation is area-specific. Interviewees who are familiar with prior phases of AgMIP note that the information that AgMIP produced for specific districts in each country is very helpful for making decisions in those districts. The challenge is to characterize how vulnerabilities and effective approaches to adaptation differ under different climate, environmental, socio-economic, and governance conditions.

A parallel challenge is to improve understanding of how information about vulnerabilities and effective adaptations that accurately reflects different conditions in the country can inform national policy. Designing policies that successfully support approaches that are tailored to local conditions requires further research.

The interviewees mention the need for understanding benefits and costs of adaptation strategies for different populations under different conditions, which requires empirical research across a range of local conditions.. Decision makers also need more studies that combine assessments of effectiveness with costs of adaptation to guide investment in adaptation strategies under different conditions.

Another research area is in communicating information tailored to different types of decision makers. Despite much attention to this topic, interviewees clearly convey that information is rarely designed to be usable by decision makers, and the gap is especially wide for decision makers at the local level. A related research area is the development of climate information services that can guide decisions, especially farmers' decisions, emerges in many interviews, particularly noted in Senegal and Ghana.

Insufficient and poor-quality data are a significant obstacle to more useful research outputs. Building capacity to collect, store, manage, and disseminate complete, high-quality climate, environmental, crop, and socio-economic data at high spatial and temporal resolutions is essential for supporting useful research.

- **Engaging with a broad set of stakeholders who work on climate change and adaptation issues in agriculture at the very beginning of the research and keeping them involved throughout the process**: Early engagement should allow for stakeholders to define the research priorities and to shape how the research is done. A principal component needed in the engagement process is to build capacity among different types of stakeholders to guide the research, to understand the research methods and results, and to understand how to use the results. The types of capacities needed and the approach to improving them is likely to differ for different types of stakeholders, such as national decision makers, local government staff, civic society organizations, and farmers.

  Information from interviews suggests that researchers should engage directly with national ministries that lead the planning processes in each country. Use of knowledge produced by a research project may be more likely if the ministries consider the project to be a trusted partner. Furthermore, such engagement can help the research team to understand the ministries' priorities, which are influential in the planning process, and to address those priorities with the types of information to which the national decision makers are likely to pay attention. A likely avenue for researchers to engage with the national ministries and with other participants in the planning process is to help develop the national planning documents that are in progress.

Interviewees encourage researchers to engage not only with lead ministries but also with all participants through coalitions and platforms that have formed to work on climate change and adaptation in the countries. These bodies can help to inform research about a range of priorities and important issues that may not be on the leading ministries' radars. The coalitions multiply potential entry points for research, disseminating awareness about the research and enabling the production of research that is useful to a broad set of actors. Participation in the development of national documents is again a potentially fruitful avenue for engaging. Also, respondents emphasize the importance of communication and coordination across all projects and research teams that are addressing vulnerabilities and adaptation to climate change in agriculture.

Respondents also express the need for a clearinghouse of country-specific information on climate vulnerabilities and adaptation in each country. Interviewees note that information is dispersed, can be difficult to find, is not necessarily accessible, and it is difficult to gauge its credibility. The more credible the information provider, the more likely the information is to be too aggregated for use in decision making.

5.6 Developing RAPs at Multiple Scales: Global, National, and Regional

The process of developing RAPs across scales builds on the RAPs development protocols used in AgMIP's Regional Integrated Assessments of climate change and adaptation (Valdivia et al., 2015, 2021). The goal is to develop RAPs at National level that describe plausible futures aligned with the countries' visions of sustainable development and climate change policies. Regional (sub-national) RAPs incorporate policy and technological interventions set at national level and provide with storylines and quantifiable parameters to be used as inputs to crop-livestock and economic models. Additional RAPs representing different plausible future can be developed to assess impacts of climate change on farming systems under different future conditions. Key to this process is ensuring the consistency across the scales.

Scales

The RAPs development approach is a nested approach that links drivers and outcomes across scales (See Figure 5.6.1).

- Global - Higher level pathways are used to define external drivers that may influence some of the National -and sub national- drivers. In AgMIP's scenario development, Shared Socio Pathways (SSPs) are used to describe the future global socio-economic conditions, including price and productivity projections. The SSPs are linked to different emission scenarios (Representative Concentration Pathways, RCPs) based on the storylines of the SSPs and what levels of emissions would be feasible under each pathway.

- National - At this level, national RAPs include policies and agricultural plans that focus on the entire agricultural sector and cover the whole country. Drivers at national level might be influenced by external factors, like those in the SSPs or other aspects like international trade, international agreements and commitments (e.g., Paris agreement). National drivers in turn, influence the Regional (Sub-National) drivers.

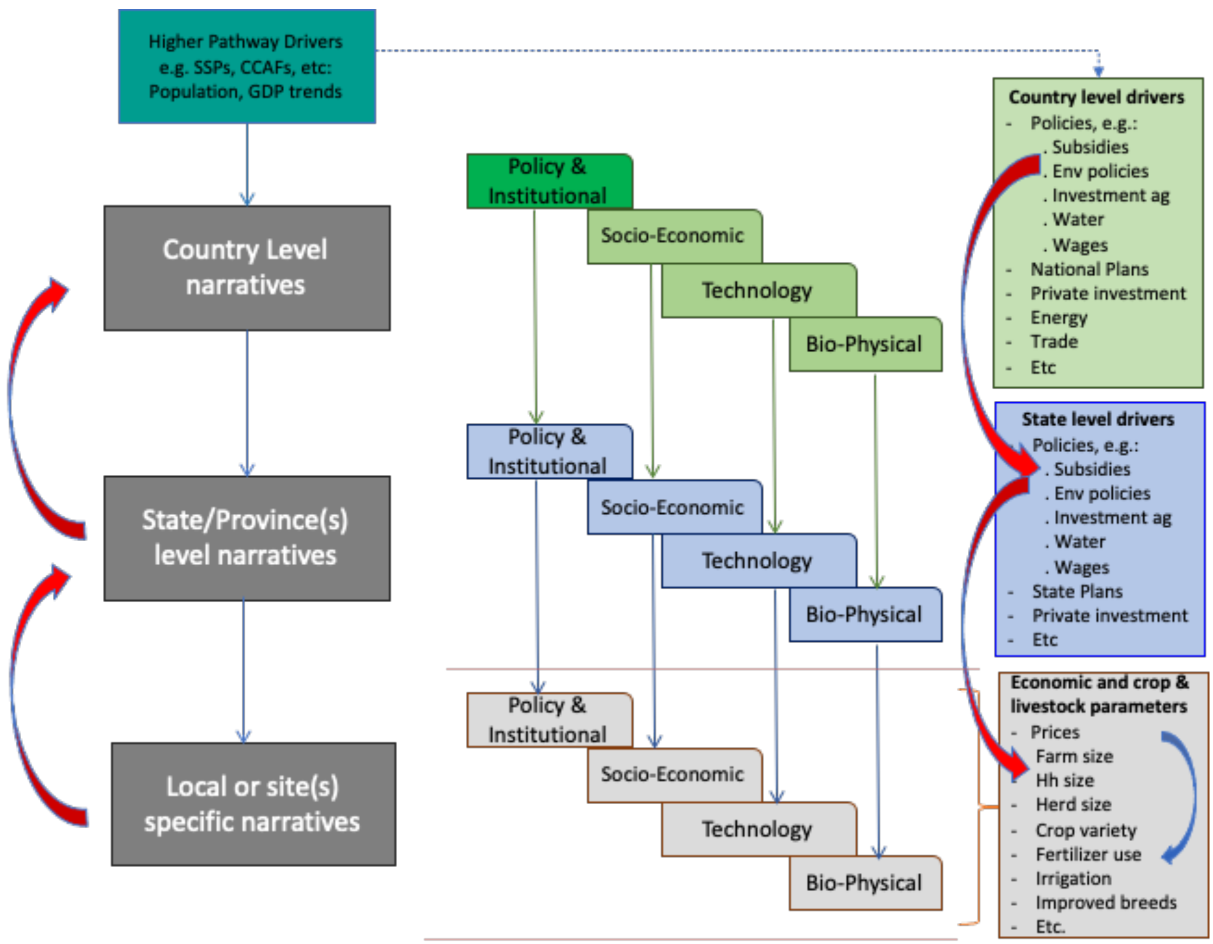


Figure 5.6.1. Nested approach across scales to develop Representative Agricultural Pathways:

- *Regional* (Sub-National*)* - At Sub-National level, we can define RAPs at two sub-levels. In cases where geographical division is important for the implementation of the national policies (e.g., State, Province, etc.), then RAPs can be developed for these levels as well as for more local -level conditions (e.g., district level, agro-ecological region, etc.). The regional RAPs contain most of the State/Province level narratives but are focused to the specific farming system to be analyzed (e.g., Crop-livestock system in Nkayi, Zimbabwe). The quantification of key drivers of these RAPs are used to parameterize crop, livestock and regional and national economics models.

Linking Regional RAPs to National RAPs

Development of Regional RAPs follow these overall steps:

1. The process starts by characterizing the current state of the farming system, including the current policy conditions.
2. Using narratives of future global socio-economic scenarios (SSPs), information about the national policies (in some cases projected into the future) and with input from stakeholders and the team of scientists and experts, a description of "future states" of the agricultural farming system are created (RAP narratives).
3. With the definition of the future scenarios, an iterative process is carried out to identify the key drivers of change (policy/institutional, economic, technology and bio-physical) that would support the RAP narrative (i.e., the future conditions of the agricultural system).
4. Regional RAP is finalized by defining qualitative and quantitative changes for key drivers. The process starts over to develop additional regional RAPs.

In the AgMIP A-Teams Project, regional and national RAPs were developed following the process described in Figure 5.6.1. The steps to link national level RAPs to regional RAPs were to:

1. Characterize the current state of the agricultural sector in the country. Use of available information to define the structure of the government, organizations and identify key stakeholders (those who can be part of the process during the project, and the high-level stakeholders to whom the results will be presented).
2. Identify and describe the long-term vision of the country using Sustainable Development plans, Strategic Vision, NAPs, etc. with a focus on the agricultural sector, but also including policies and plans from other sectors that may have an effect on the agricultural sector (e.g., energy, health, education, etc.).
    - The strategic vision or sustainable development plans usually have key pillars around which policies and interventions are built to achieve goals regarding environmental protection, achieve economic efficiency, agricultural sustainable development, energy production, social equity, food security, etc. In many cases a set of indicators are associated with these plans.
    - The goal was to develop contrasting RAPs, thus, after finalizing the RAPs that represent the future state under the strategic visions or country's sustainable development plans, a similar iterative process to create additional RAPs was followed, then pathways representing Business as Usual (BAU) and Unsustainable Development conditions were developed.

3. Using the above information, and the defined global SSPs, the team, invited experts and stakeholders define the plausible future states of the agricultural sector and crafted the main 'RAP narratives'.
    - The next step is an iterative process that starts with identifying the key drivers of change (use of the strategic vision, sustainable development plans, and other documents to determine these drivers). National and agricultural policies define the policy/

institutional and socio-economic conditions of the National RAPs. The Policy Matrix (defined below) was used to identify the different types of policies that supports contextualizing the RAP and define the key variables that may have a direct or indirect effect on the sub-national level drivers. Examples of drivers and specific variables are shown in Table 5.6.1.

- Once we identified the key drivers, a process similar to the regional RAPs is followed. Using the DevRAP matrix, for each driver, a direction and magnitude of change is proposed. Storylines to justify these changes are elaborated and levels of agreement are assessed.
- Variables were assigned to team members, experts and stakeholders to research about the plausible trends following the overall narrative. All documents, studies, papers, etc. used were documented and stored on a shared Google Drive folder.
- The team revised the storylines as they are crafted to make sure there is internal consistency across the drivers.
- The output of the iterative process is a full draft of National RAPs.

Table 5.6.1. Example of drivers and variables for National level RAPs

Driver	Variables
Regional Development	Context: Regional; West Africa (ECOWAS)
Economic growth	GDP, Agricultural GDP share
Population	Population growth, migration rural to urban
Literacy	Education-investment, programs
Healthcare	Investment on healthcare, programs
Land Use	Expansion, change to new crops (as policy, incentives, land protection, etc)
Energy	Fossil fuel use, policies
Agricultural policies	Subsidies, taxes, quotas, policies on specific commodities, Payment for Ecosystem Services
Food production policies	GMOs, organic, etc
Environmental policy	Conservation policies, etc
Climate change policies	NAPs, NDCs strategies
Trade policies	tariffs, imports/exports
Technological change	R&D investment
Water	regulations, bio-physical conditions
Biodiversity	Regulations on biodiversity, incentives, PES
Level of governance	National and Sub-National
Sub-national development	Rural development policies
Social policy	Education, equity (gender)
Markets	Investment, infrastructure, price controls/ceiling

- The next step is to revise the regional RAPs to make sure there is consistency across scales.
- The team and stakeholders meet and review and discuss the full Regional and National RAPs.

4. New RAPs are then developed by following the same iterative process with the main goal of identifying those drivers that would lead to an alternative future state (e.g., a less sustainable development oriented RAP).
5. The quantification of the revised regional RAPs will be input to the TOA-MD model and complement the data needed to implement the RIA.

Mapping National Policies to RAPs

In order to help with the process of identifying the key drivers from National policies and link them to the RAP process, we use a Policy Matrix tool created in Excel (Mapping national policies to RAPs.xlsx).

This matrix lists all drivers and specific variables that are key to describe the national and agricultural policies in the context of the country's strategic vision, sustainable development plans and climate change plans (NAPs, NDCs, etc). The matrix also allows to identify how they may influence regional RAPs and how they are influenced by global scenarios (SSPs).

The policy matrix (illustrated in Figure 5.6.2) helps to categorize the type of policies as: (1) enabling; (2) Incentivizing; (3) Mandatory; (4) Climate policies; and (5) Guidelines or programs implemented or planned by the government. The team uses this matrix to evaluate the importance of each policy and how these can be incorporated and quantified in the different RAPs. In addition, climate policies are used to develop assumptions about the implementation of future climate policies (Shared Policy Assumptions).

5.7 Establishing a Framework for Integrated National and Regional Assessments of Agricultural System Adaptation to Climate Change

Here, we provide an overview of the framework for Integrated National and Regional Assessment (INaRA). The fuller framework document with guidance on the development of protocols for INaRA is provided in Annex 13.3.3.

INaRA Goals and Approach

The principal goals of INaRA are to:

- Analyze the country's agricultural sector performance under current and alternative strategies to implement its national adaptation plan (NAP), using stakeholder-defined performance indicators, national data and national impact assessment models;

- Complement and support regional integrated assessment (RIA) of agricultural system risks and adaptation at the regional (sub-national) level by regional teams of stakeholders and scientists.

A National Adaptation Plan (NAP) is a part of the ongoing process developed by the UNFCCC to identify medium- and long-term adaptation needs, and develop and implement strategies and programs to address those needs. For example, a NAP could establish the amount of funding earmarked for agricultural research on climate adaptation, and alternative strategies for implementation could establish priorities for particular regions and production systems in the country.

To achieve these two goals, INaRA begins with the identification of a set of scenarios defined over a stakeholder-defined planning horizon. Each of these scenarios is comprised of two main components: a strategy for national adaptation plan implementation; a future pathway comprised of projected future climate conditions (associated with Representative Concentration Pathways, or RCPs); and socio-economic conditions (represented by global Shared Socio-economic Pathways, SSPs, and national Representative Agricultural Pathways, RAPs).

INaRA uses quantitative modeling to evaluate the performance of the country's agricultural sector and main agricultural systems for each scenario using stakeholder-defined performance indicators for each scenario (Figure 5.7.1). These indicators can be measures of agricultural productivity, prices, food consumption, food stability and other environmental and social indicators discussed in this report.

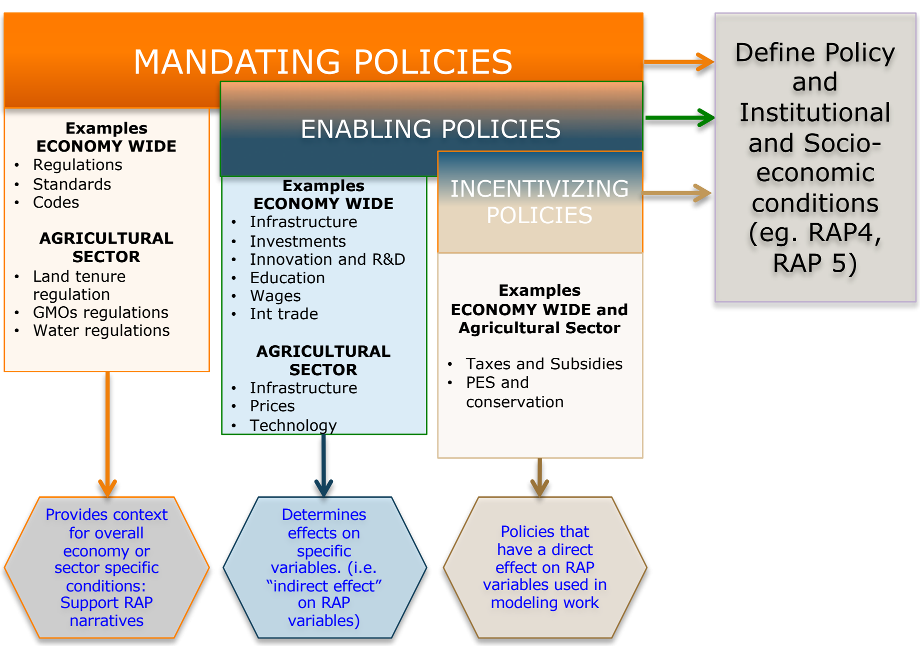


Figure 5.6.2. Components of the Policy Matrix tool: National level Policies and linkages to RAPs.

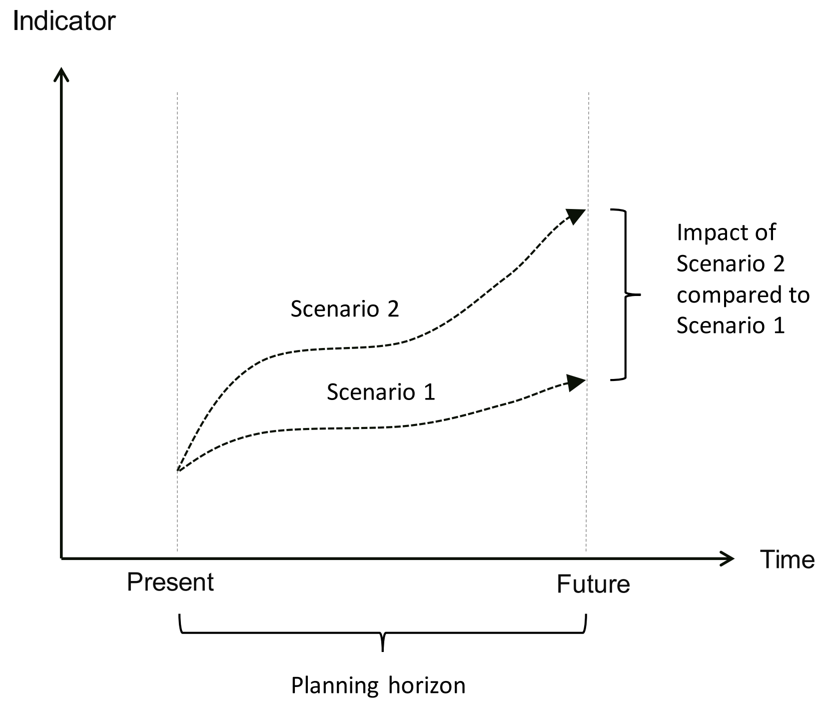


Figure 5.7.1. INaRA scenario design to assess alternative adaptation strategies. Each scenario is composed of an adaptation strategy and projected future climate projections (SSP-RCPs) and socio-economic pathways (RAPs). For example, Scenario 1 could be a "baseline" or "business as usual" scenario without adaptation and Scenario 2 could be a scenario with a specified National Adaptation Plan and a set of system-level adaptations.

Using this approach, model simulations allow national stakeholders to evaluate alternative adaptation strategies, compare the range of plausible outcomes achievable with alternative adaptation strategies. The modeling methods also provide stakeholders with a way to evaluate the uncertainty associated future climate and socio-economic pathways, as well as uncertainties associated with the models used.

INaRA Modeling: Design and Implementation

INaRA modeling is designed to project the future value of aggregate economic indicators (e.g., aggregate commodity productivity, production, consumption and prices), environmental indicators (e.g., greenhouse gas emissions, water, and air quality, aggregate fertilizer and chemical use), and social indicators (e.g., national per capita income and poverty rates, per capita food consumption and food security). The differences in the data and models at these scales create major challenges to INaRA implementation. For example, national analysis typically operates on an annual time step. In contrast, regional integrated assessments (RIAs) may operate on seasonal time steps suitable to farm systems and households and corresponding indicators such as farm income, crop production and yields, regional poverty, household food security. These time steps typically do not begin or end with the annual calendar. The entire agricultural sector of a country is comprised of many components from farm to national scales that are jointly and dynamically determined in space and time. However, due to the data and analytical challenges, it is not currently possible to simulate these large, complex systems at both regional and national scales as one large model.

The solution proposed here is to develop a process that involves both formal modeling at national and regional scales, as well as informal, expert-judgment processes to make linkages and ensure logical consistency between national and regional modeling. A spreadsheet tool, the "National-Regional Data Interface" (NRDI), provides a common set of identifiers and other information that enables coordination between scales (Figure 5.7.2).

INaRA aims to support a country's ongoing NAP process as well as related policy decision making. Critical elements of INaRA are therefore coordination with national institutions leading the NAP and committing resources to support the INaRA activities. Given the available resources, national and regional modeling teams need to be established and participate in the design of INaRA in collaboration with the NAP team and other institutions involved in related policy decision making.

The first step in INaRA is to make decisions about key components jointly with national stakeholders:

- national impact indicators to be included (quantitative and qualitative)
- national modeling team components and membership (climate, production systems, economics, environmental, and social component)
- regions & systems to be included, and members of regional teams to implement RIAs
- a work plan for national assessment and coordination with regional teams.

The national assessment is designed and implemented in coordination with a set of RIAs for each major region and agricultural system in the country. RIAs provide region- and system-specific analysis to support the national-level policy design and implementation. A key feature of an RIA is the regional and agricultural system-level specificity needed to design and evaluate farm-level adaptations effectively. The AgMIP *Guide for Regional Integrated Assessments: Handbook of Methods and Procedures, Version 7.0.* http://agmip.org) describes methods for the regional assessments. In many cases, the RIA methods will need to be adapted to fit the data availability, resource constraints and priorities of a specific country's INaRA.

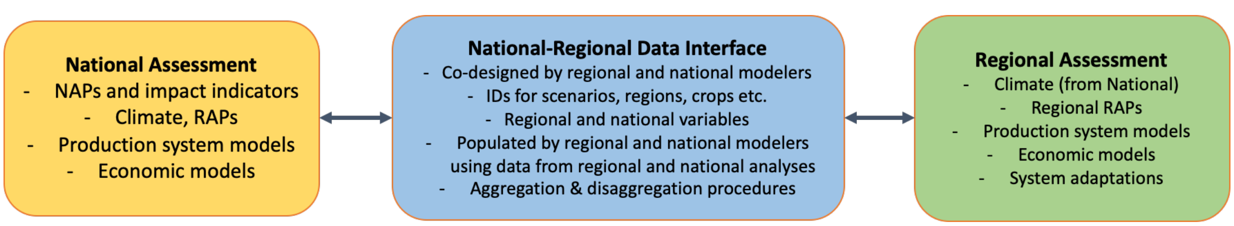


Figure 5.7.2. Linkage of national and regional (sub-national) modeling through the National-Regional Data Interface (NRDI)

National Indicators

A variety of economic, environmental and social indicators can be used, depending on data availability and the available models. Here we group indicators according to the three broad areas of sustainable development – economic, environmental and social (see Table 5.7.1). There are a number of systems of normative goals and indicators that are now being used. For example, progress towards the seventeen UN Sustainable Development Goals is measured with multiple indicators for each goal, and many of the SDGs are directly related to agriculture. The CGIAR has identified five specific impact areas: nutrition and INaRA implementation will involve a set of iterative steps to coordinate national and regional analyses. Figure 5.7.3 illustrates the main components and linkages in INaRA. In reality, national and regional outcomes are jointly determined in a complex, dynamic process creates a methodological "chicken-and-egg" problem. For example, national analysis requires estimates of regional system productivity; however, regional productivity depends on nationally or internationally determined prices. The national and regional teams will need to establish a set of initial assumptions to populate the NRDI, and then establish a schedule to coordinate national and regional analyses and iteratively update the NRDI.

An important limitation of model-based integrated assessment is the "bias" towards quantifiable indicators, with the consequence of often ignoring some environmental or social impacts that are difficult to quantify with available models. For example, Antle and Valdivia (2020) discuss the models that are available to quantify indicators related to the CGIAR's five impact areas, as well as the relevant impacts that are not currently quantifiable with models. To address this limitation, they recommend a stakeholder-based process that first identifies relevant outcomes and impacts in each of the three dimensions of sustainability, and then addresses how relevant indicators – both quantitative and qualitative – can be incorporated into the analysis. We envisage a similar approach for the identification of national and regional integrated assessment indicators. A process similar to the development of Representative Agricultural Pathways (RAPs) is appropriate for this purpose.

Table 5.7.1 Economic, Environemntal, and Social Indicators

Economic Indicators	Environmental Indicators	Social Indicators
Commodity productivity (i.e., crop yields)	Land area cultivated by conventional or conservation tillage	Income distribution (poverty rates, urban and rural)
Commodity area and production	Soil erosion	Food security (various objective and subjective indicators; national, urban, rural)
Local commodity consumption	Agricultural chemical use: organic and inorganic fertilizers, pesticides	Gender equity (education, labor participation, asset ownership, income)
Agricultural commodity prices	Energy use	Health (life expectancy, urban and rural, by gender and age)
Agricultural commodity trade (imports, exports)	Irrigation and water use	
	Net greenhouse gas emissions (carbon dioxide, nitrous oxide, methane)	

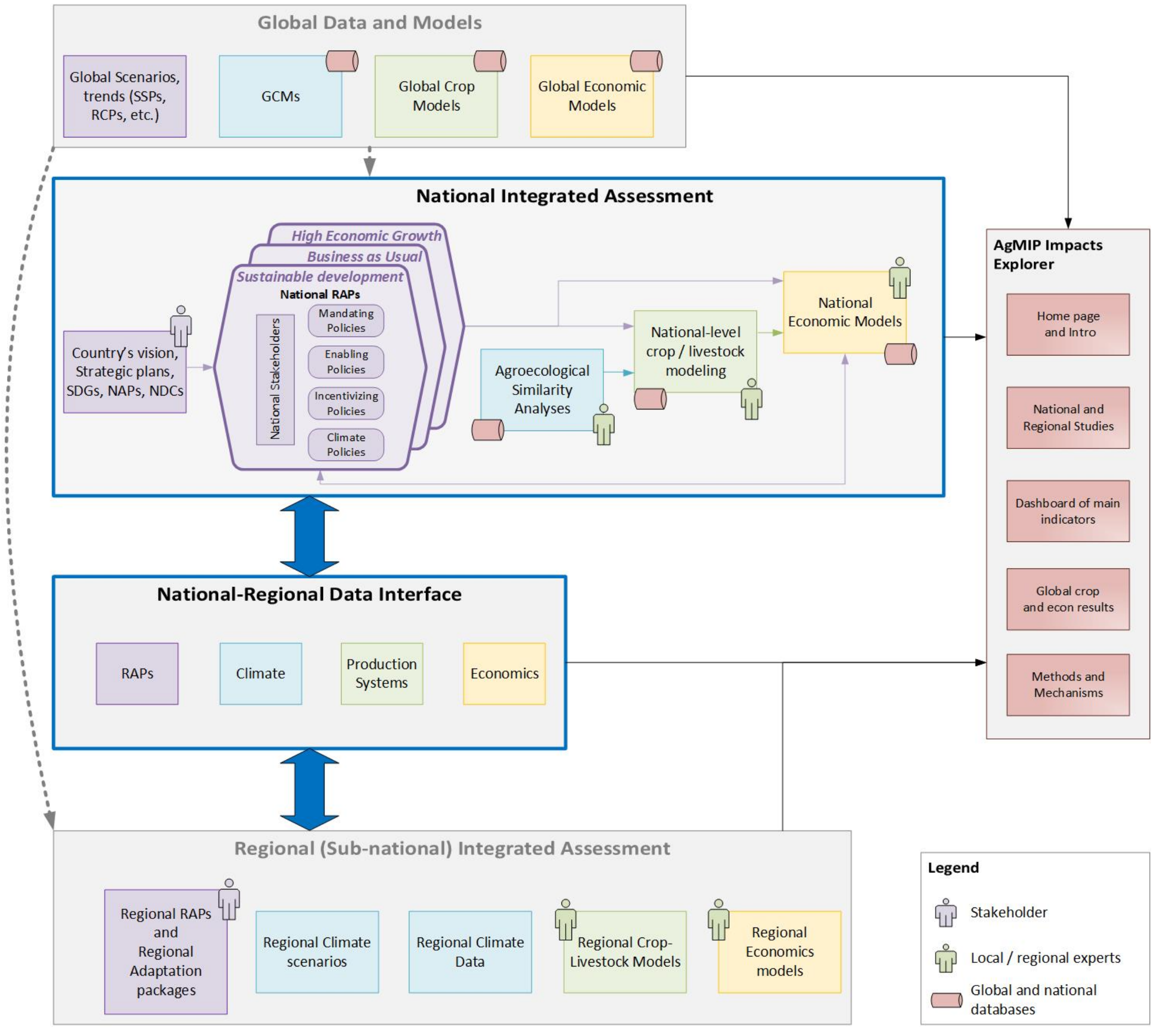


Figure 5.7.3. INaRA Components and Linkages.

An important aspect of the RIA method is to quantify vulnerability of farm households to climate impacts and the effects of adapting farm household systems to climate change. In addition to income vulnerability, food security indicators and indicators related to assets such as livestock can be used. This is an area where national models are very limited in their capability to represent impact, thus alternative methods should be explored. For example, review and synthesis of existing regional vulnerability studies, together with RIA vulnerability assessment, could be used to identify vulnerable regions, systems and populations. This information could be combined with national modeling to translate and disaggregate national outcomes into implications for vulnerable regions and groups.

5.8 Environmental Impacts – Assessing Adaptation and Mitigation Co-Benefits

Given the importance of livestock to smallholder diversification, as well as the increasing interest by Zimbabwean stakeholders in promoting livestock smart alternatives that contribute with the country's mitigation goals (e.g. NDCs), the potential co-benefits of adaptation and mitigation were evaluated for Nkayi. This section presents preliminary results. Figure 5.8.1 shows that, for all scenarios tested, methane (CH4) from enteric fermentation is the largest contributor to GHGs followed by direct nitrous oxide (N20) fluxes from soil and methane from manure.

The adaptation packages under the SD pathway were designed to assess possible adaptation-mitigation co-benefits. The adaptation package A1 included switching to drought tolerant varieties, the adaptation A2 added improvements for livestock feed supply and introducing *leaucaena* into the cropping system. The third adaptation package A3, builds from the previous

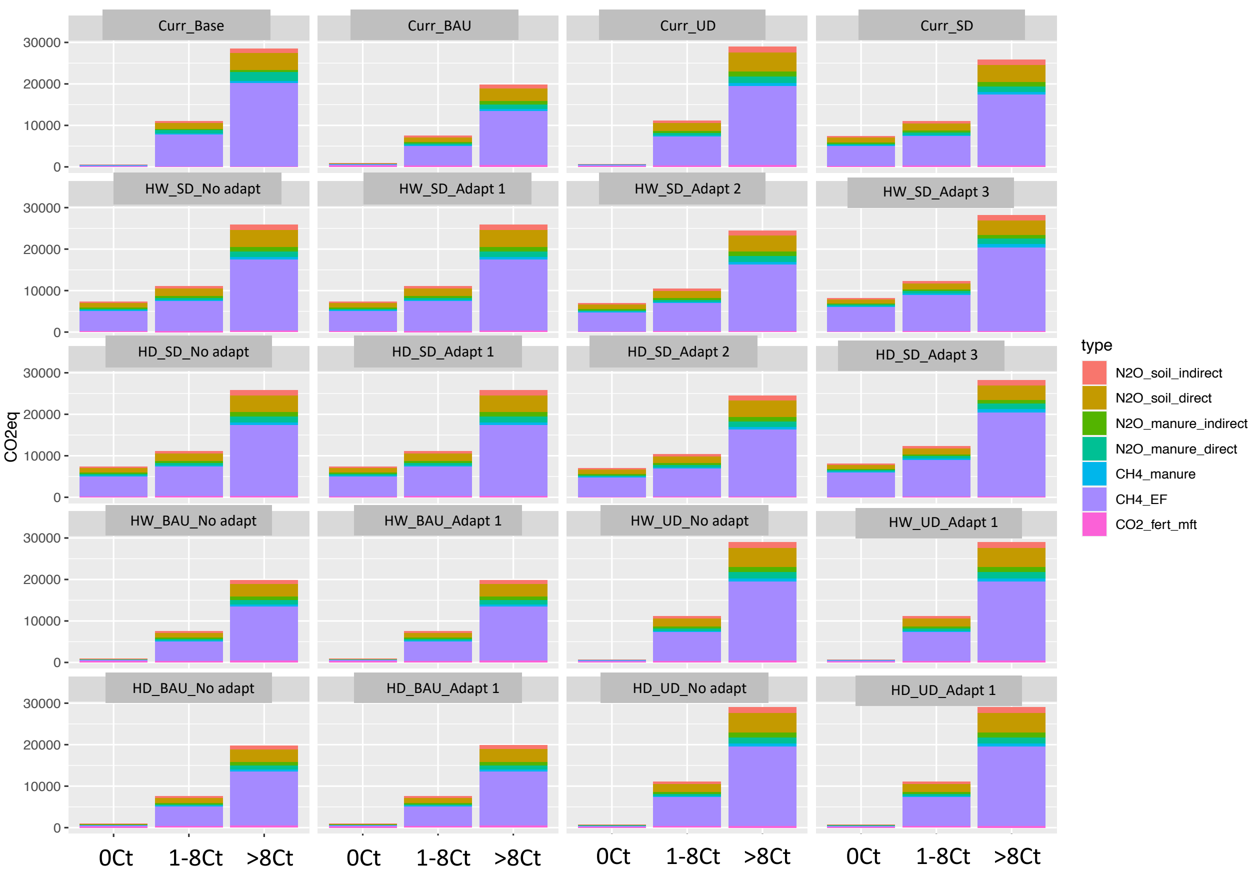


Figure 5.8.1. Estimated GHG emissions under current and future conditions (3 RAPs), climate change impacts and adaptations by farm types in Nkayi, Zimbabwe. HW=Hot-Wet climate; HD=Hot-Dry climate; Curr=Current conditions, no climate change; BAU=Business as Usual; SD=Sustainable Development; UD=Unsustainable development; Adapt x=Adaptation packages, x=1,2,3; No adapt=climate change and no adaptation. Preliminary results.

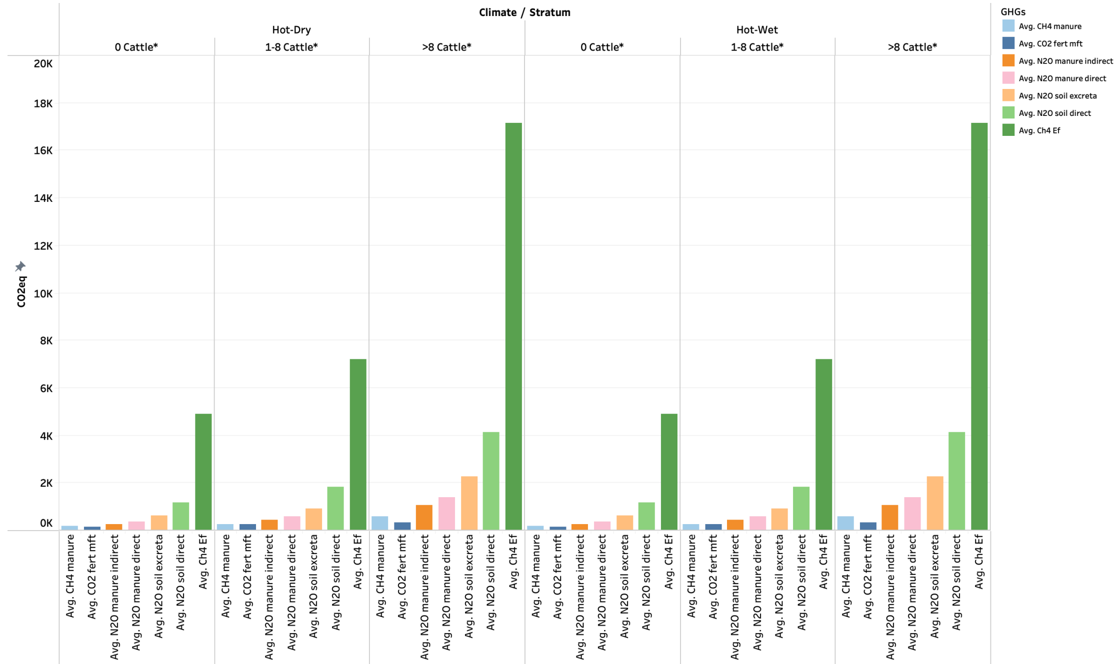


Figure 5.8.2. Estimated GHG emissions for Nkayi, Zimbabwe under future conditions (SD pathway) and with climate change. Results are aggregated by climate scenario and stratum.

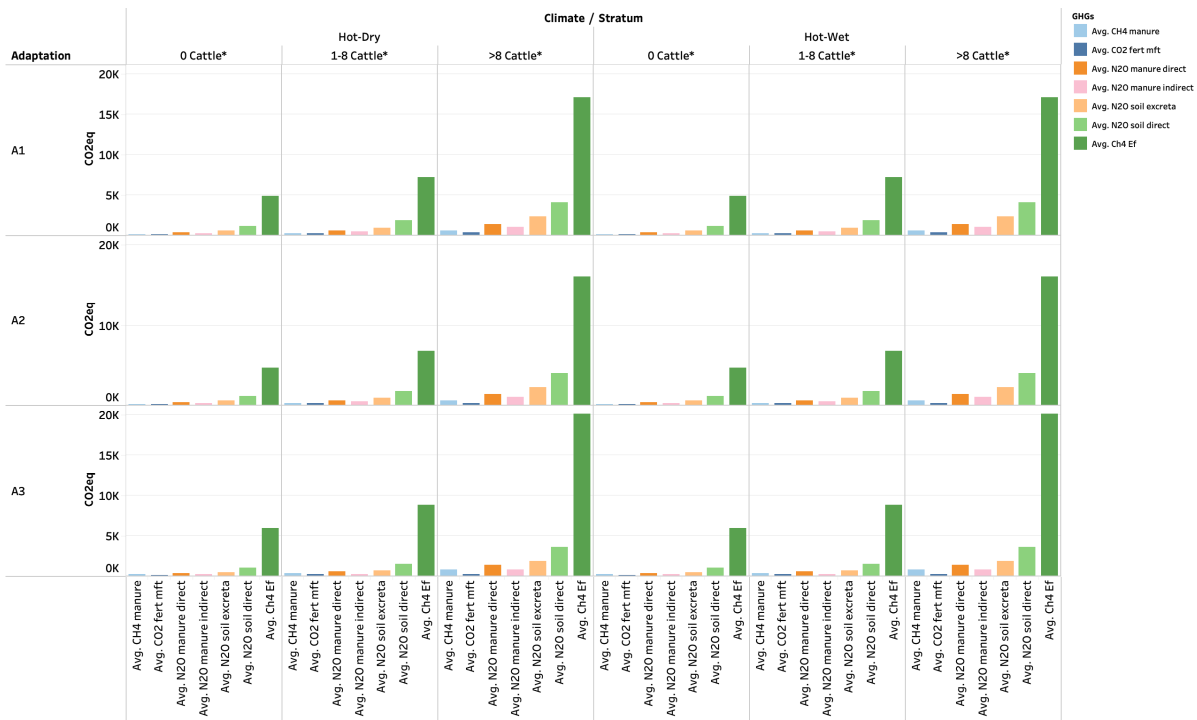


Figure 5.8.3. Estimated GHG emissions for Nkayi, Zimbabwe under future conditions (SD pathway) and with climate change adaptations. Results are aggregated by climate scenario and stratum. * The farm type labels correspond to the characteristics of the farms before adaptation. The adaptation packages increase herd sizes across the population, including farms that did not have cattle before.

AgMIP DFID work, but switches from cattle to goats (See Annex 13.3.2 for details). In order to assess the contribution of the farm activities to total Greenhouse emissions (GHGs), different sources of emissions were estimated for the different scenarios. Figure 5.8.2 shows the estimated GHG emissions aggregated by stratum and climate scenarios for future conditions (SD) with climate change.

The adaptation package as defined above include elements aimed at improving feeding availability while at the same time improving soil health. This included changes in land allocation and introducing a high yielding tree, Leucaena. The estimated GHGs under these scenarios are shown in Figure 5.8.3 (prior page). Methane from enteric fermentation, and nitrous oxide from soils seem to be the largest contributors to GHGs emissions. The lower emission levels from farms in strata 1 are caused by the small herd sizes on these farms, compared to strata 2 and 3.

Figures 5.8.4(a-c) show the trade-offs between the difference in farm net returns and the estimated changes in methane emissions from enteric fermentation and in the total GHG emissions for each farm, if they were to switch to one of the adaptation packages. The adaptation package one (A1) is based on improving cultivars with little implication for livestock and emissions, resulting in a near-vertical blue line of points in Figures 5.8.4(a-c). The difference in GHG emissions across the strata is substantial but expected due to the larger herd sizes in strata 2 and 3. Trade-offs between farm net returns and GHG emissions means that increasing net returns may increase GHG emissions and vice versa.

However, in the case of adaptation package A2, there are some farms that would decrease GHG emissions while also increase net farm returns. The NW quadrant represents the win-win outcomes (increasing net returns while decreasing GHG emissions). The SW quadrant shows a

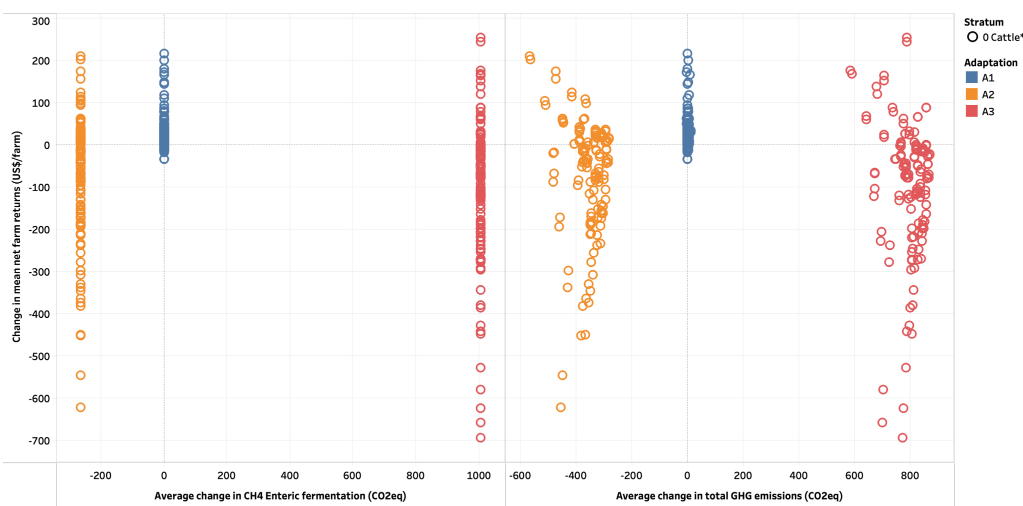


Figure 5.8.4 (a) Change in mean net farm return compared with CH4 enteric fermentation (left) and the average change in total GHG emissions (right) for stratum 1 (no cattle).

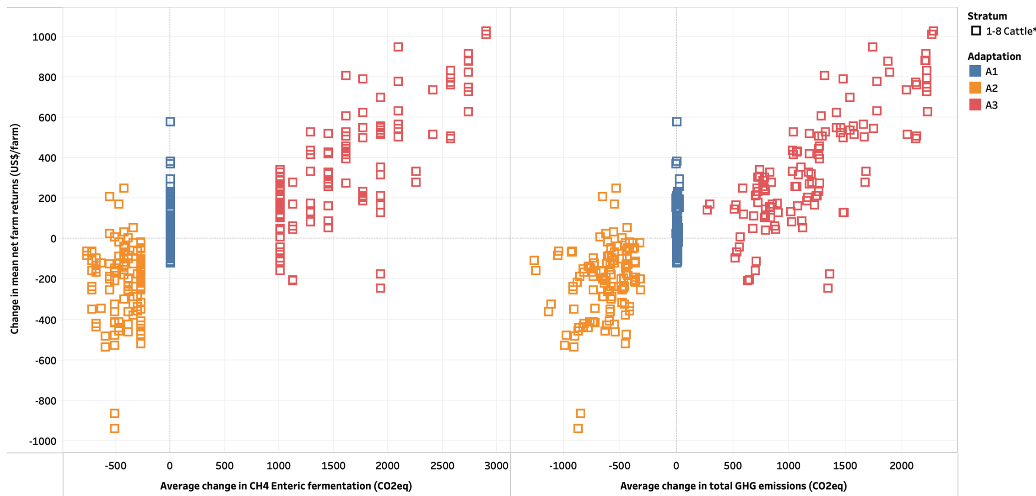


Figure 5.8.4 (b) Change in mean net farm return compared with CH4 enteric fermentation (left) and the average change in total GHG emissions (right) for stratum 2 (1-8 cattle).

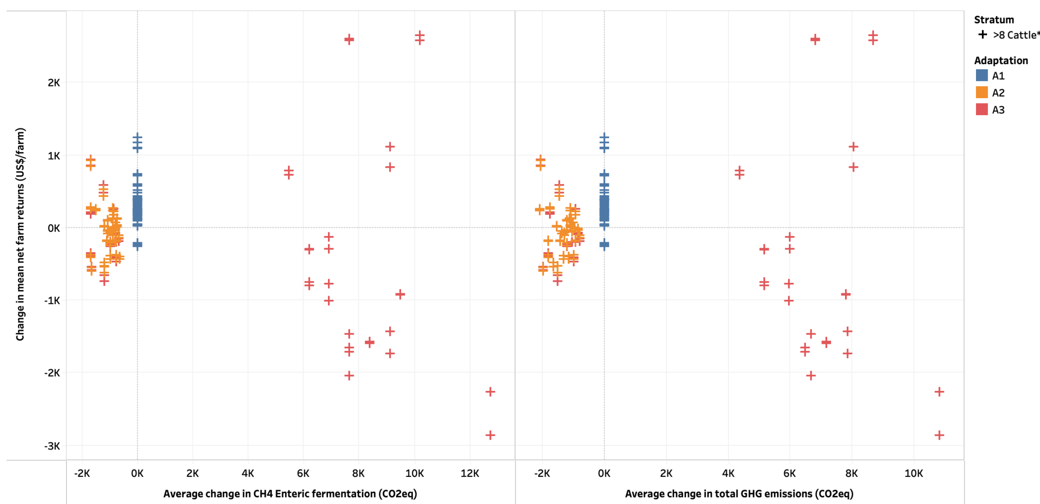


Figure 5.8.4 (c) Change in mean net farm return compared with CH4 enteric fermentation (left) and the average change in total GHG emissions (right) for stratum 3 (8 or more cattle).

lose-win situation, where GHGs are reduced at the expense of reducing net farm returns. The SE quadrant is the worst-case scenario or lose-lose situation where GHGs are increased while net returns decrease. The NE quadrant shows the win-lose case where net farm returns increase at the expense increasing emissions.

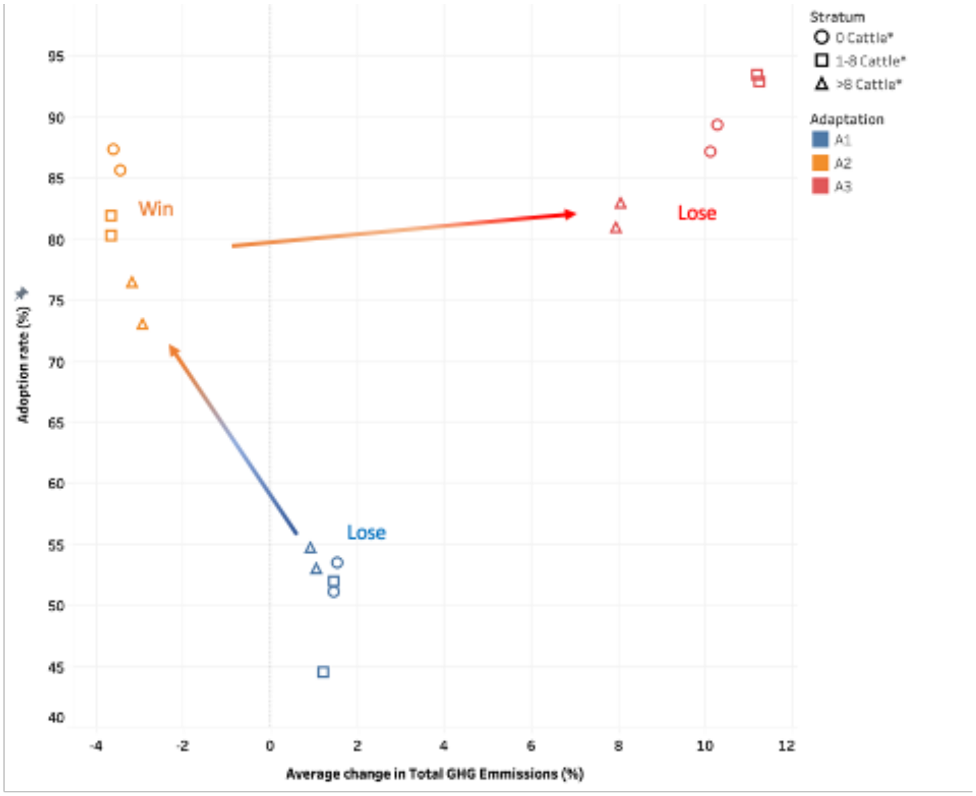
The results suggest that pushing farmers to adopt the adaptation package 3 (AP3) may increase emissions substantially, however, as described above, farmers' livelihoods would improve (i.e., poverty rates and food insecurity will decrease). AP2 on the other hand may provide win-win conditions for some farms, but there are farms that may also lose. The previous analysis assumes that every farm would switch to the adaptation package. The TOA-MD model was used to assess the potential adoption rates for each adaptation package and the socio-economic and environmental impacts associated to that adoption. Methane from enteric fermentation and the total GHG emissions were used in the analysis to test the mitigation effects. For this preliminary assessment only results from APSIM were used.

A table of results from this analysis can be found in Annex 13.3.2. Adoption rates for the adaptation package one (A1) range between 45% to 55% across the two GCMs while adaptation packages A2 and A3 have much higher adoption rates (73% - 94%). Impacts on socio-economic outcomes have been discussed in detail in previous sections, in all cases farm net returns increase and poverty rates decrease. What is important to note is the magnitude of the impacts, adaptation packages A2 and A3 provide larger increases in net returns and do a better job decreasing poverty rates. The environmental impacts show that adopting A1 would result on a small increase in methane emissions and overall GHGs. This small increase, between 1% to 2%, is expected because the adaptation package is focused on improving cultivars and have small effect on livestock production.

The adaptation package A2, on the other hand shows a decrease in emissions. This suggests that improving livestock feed availability and quality could transform the income-GHG tradeoffs in win-win outcomes. High adoption rates of this adaptation package indicates that a large proportion of the farmers' population in the region would benefit from the adaptation while contributing to mitigate emissions.

The A3 adaptation package transforms the livestock system by switching cattle to goats. The results show that GHG emissions increase substantially with this adaptation strategy, but also provided much higher benefits in terms of increasing net farm returns. Part of the explanation for the high increase in emissions is that in the design of the adaptation package, it was assumed that farmers may need to convert from cattle to goats maintaining the same level of TLU (Tropical Livestock units), therefore, farmers ended up with a large goat herd size. Additional analysis or sensitivity analysis is needed to test how trade-offs can be minimized or changed to synergies. Other benefits that may provide this adaptation package (e.g., benefits to women and youth) have not been captured in this analysis.

These results raise the questions about how to implement adaptation strategies, what outcomes become more important for policy decision makers and if the adaptation strategies should be implemented in the same way for all farms (i.e., for all farm types) and what information is needed to design adaptation and mitigation strategies. Using these preliminary results, Figure 5.8.5 shows the possible pathways for implementation of adaptation-mitigation strategies and the associated trade-offs. Clearly, if increasing income (and reducing poverty, etc.) is the priority, then Adaptation A3 would be the preferred option. This might be the case if the potential gains from mitigation are small and the contribution to the overall mitigation efforts of the country is not significant. However, if environmental benefits are part of the priority, then A2 would be the best alternative, at the expense of lower economic gains. However, even in the case where A3 is the preferred alternative, not all the strata respond the same way. In fact, for stratum 1 the adaptation A2 would be the best option in all cases



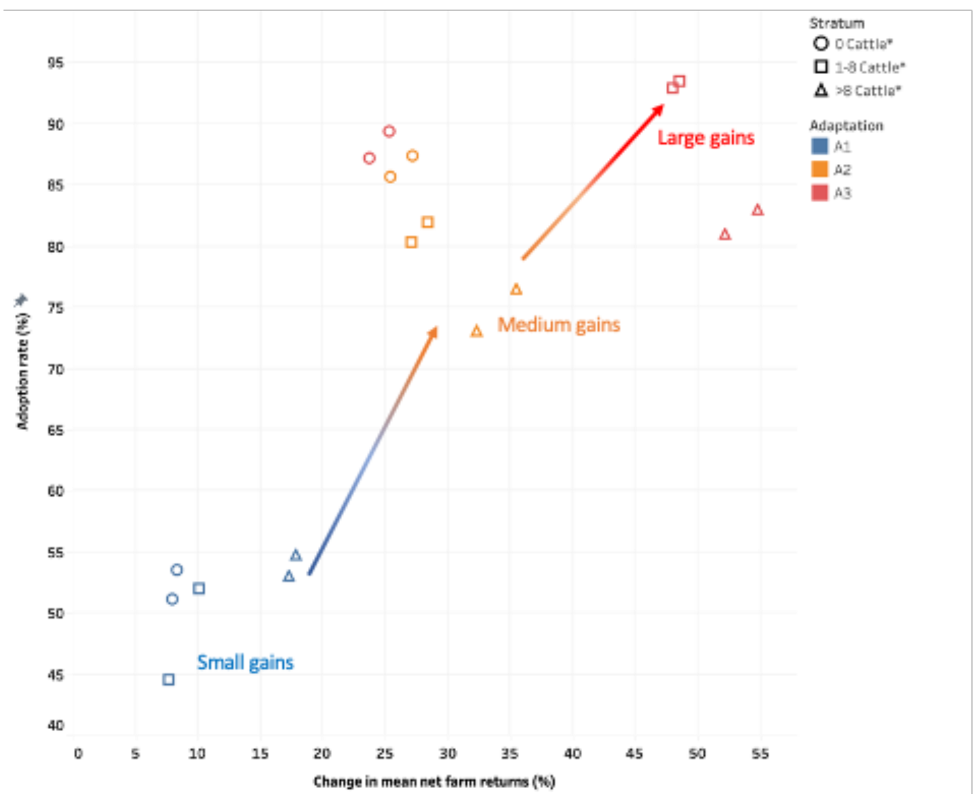


Figure 5.8 5. Pathways to win-win economic and environmental outcomes.

compared to strata 2 and 3. While adoption rates for the A2 package are already high, in this and other cases where there is the need to increase adoption, other programs that incentivize adoption, such as payments for eco-system services, might be needed.

While the preliminary results of this study are focused on a small region in Zimbabwe, the analysis above have important implications for the design and implementation of adaptation-mitigation strategies. Furthermore, it shows the kinds of information that AgMIP-CLARE can produce to support policy decision making.

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6. Managing Risks

6.1 Ghana

COVID-19 proved to be a major handicap to this project. This pandemic prevented the more effective in-person or face-to-face approach to stakeholder surveys and data collection. In-person team meetings were restricted in terms of the duration of each meeting and frequency. This meant extra efforts and staff time had to be committed to ensure proper execution of the project activities. The COVID-19 challenge was resolved by increasing on-line methodologies. Interviews of stakeholder were conducted by telephone while surveys employed on-line methods (e.g., Monkey-survey). Zoom meetings and webinars were utilized to enhance engagement with stakeholders even though it could not completely make up for the confidence building of in-person meetings, an important ingredient for effective engagement with stakeholders. The challenge improved the capacity to use on-line tools to administer surveys.

The internet-based approaches adopted also met with some difficulties, especially as power outages are frequent and internet connectivity is often problematic in Ghana. In some cases, respondents were slow to respond, necessitating the extension of survey duration, among others.

To ensure that the engagements (workshops) produced expert outcomes, the A-Team members drafted in advance materials such as RAPs narratives, that were intended to be developed together with the stakeholders prior to the engagement. The draft materials were shared at least a week prior to engagement to enable review prior to the physical meeting. Inter-personal interactions, which are necessary for effective stakeholder engagement, were limited.

At present, the Ghana A Team lacks sufficient socio-economic expertise to advance the methodologies independent of Base Team mentors, given that the predominance of biophysical training offered to persons interested in advance degrees in the agricultural sector. Avenues to admit and train new A-Team members in AgMIP socioeconomic methodology was not possible within this project, given the relatively short duration. Yet, the A-Team worked hard to broaden its scope of knowledge and expertise, to the best of its ability.

6.2 Senegal

One of the main risks faced during the project was the pandemic context. Covid-19 required rethinking how several activities should be carried out in the project framework. In March 2020, as a response to increasing Covid-19 cases in the country, the Government introduced curfew alongside restriction mobility measures. They slowed the initial project chronogram and implied a revision of due deliverables dates. This resulted in rearrangements in the different deadlines of the project. As a result, the A-Team held most of its meetings online. In addition, we planned all the interviews with key stakeholders (e.g., for the mid-project baseline, monitoring, and evaluation report) virtually. RAPs development with stakeholders was quite challenging as in-person sessions are vastly more efficient for these types of discussions. The team elected to break the planned in-person workshop into a sequence of short online sessions, with a single in-person session for a smaller set of stakeholders, to take stock of the validity of findings in a somewhat more piecemeal manner. To be efficient with time requirements of the fast-track project, the team also had several internal meetings to identify RAPs drivers, their direction of change, and the rationale (storyline) behind the change. Online sessions with stakeholders generally started with a presentation of AgMIP goals, and the work done by the team on RAPs. Stakeholders were then provided time to react to the suggested drivers and to provide recommendations to improve the framework. With COVID-19 present over the entire study time, we ensured that safety measures were fully considered during limited, in-person workshops (November 2020, April 2021, and September 2021). Indeed, we targeted a restricted number of stakeholders and set the meeting rooms up to allow distancing. Meanwhile, we distributed masks and hand sanitizers to all participants.

6.3 Zimbabwe

COVID-19 and mitigation measures restricted efficient work flows as A-team members and participants were compromised through COVID19 implications at their work space and personal situation. Key challenges included:

- Delays in the process that required extra effort and staff time
- Network problems contributing to communication challenges within the A-team and with participants/experts and stakeholders
- The coincidence of the pandemic arriving following a series of drought years, which aggravated food insecurity and poverty, and a newly formed government reviewing agricultural and climate policies, resulting in a sense of urgency to strengthen research policy collaborations at a time that was also very restricted, in terms of actions.

Not being able to hold physical meetings limited the co-creation of scenarios and validation of results, actions considered vital for the sharing of multi-disciplinary perspectives, common understanding, and buy-in into the process.

We adopted an approach whereby the A-team drafted scenarios, simulation results and key messages for revision by experts and stakeholders. This was possible given that A-team members represented organizations with expertise and networks related to climate change adaptation in agriculture, including

- Climate Change Management Department as focal entity for climate action, NAP and NDC processes, for internal revision and relevance for national policy processes
- Regional research organizations, Matopos Research Institute (applied and extension-oriented research) and Lupane State University (academic research and capacitation programs) for drafting climate change and agricultural policy relevant information

- ICRISAT for process facilitation, conceptual and technical knowledge, dissemination and communication support, drawing on wider networks on climate change adaptation and sustainable agriculture, including CCAFS.

Feedback from participants was collected through a series of iterative steps, small physical and virtual meetings and individual interviews. The Iterations were structured as

1. Preparatory knowledge generation and planning meetings among the A-team and with AgMIP colleagues, to make use of baseline information, update scenarios, adaptation packages and agro-ecological similarity approach, discuss results and revision with technical experts and policy makers.
2. Preliminary learning and review workshops, physical and virtual, with small groups of multi-disciplinary technical experts, including advisories to policy processes, to present and revise drivers, scenarios and adaptation packages, agroecological similarities, and to brainstorm on ways to further engage with national processes.
3. Final review and validation meetings with selected national-level policy and decision makers to strategically place key messages into policy language and to identify how outcomes could be effectively endorsed for their uptake and impact.
4. Dissemination and validation webinars: Hosted by the Climate Change Management Department and Ministry of Agriculture, validation webinars were planned with the relevant Ministries, research organizations and development agencies to create wider buy in for uptake and partnerships to continue beyond the AgMIP A-Teams Project.
5. Finally, the AgMIP A-Team Project research approaches and outcomes, incorporated into existing implementation programs and networks for scaling, were further explored through individual virtual interviews with key decision-making organizations, including the A-team organizations. This process revealed a rich picture, with opportunities for the AgMIP A-Teams Project outcomes to support linkages between national research – policy processes and implementing organizations, documented in the testimonials.

Given the delays in climate action and planning processes, CCMD (the national partner and focal point for climate action) affirmed that the AgMIP A-Teams Project outcomes will be incorporated into the formulation of NAP which is to be finalized in 2022, and the NDC implementation action plan.

Despite these challenges, the advance drafting of outputs, and the convening of smaller review meetings with technical experts and policy makers, also facilitated strong commitments by participants, with momentum on which to build our future efforts.

6.4 Impacts Explorer

The main challenges faced were related to the COVID-19 pandemic and the resulting delay in research results.

The COVID-19 pandemic had a big impact on communication and collaboration within the project and with stakeholders and users of the Impacts Explorer. Although the online A-Teams Project meetings were held frequently and were well attended, the medium (mostly Zoom meetings) and connection problems affected the breadth and depth of the information exchange with project team members.

For the design and development of the Impacts Explorer, the restrictions owing to the pandemic also had major consequences. In a user-centred design approach, frequent interaction with target user groups is essential. Because the in-person meetings and stakeholder workshops were cancelled, direct contact with users for requirements analysis was not possible and the Impacts Explorer design could not be tested. The Wageningen Base Team responded by relying on feedback from the A-teams, using feedback from earlier phases of work, and applying generalized 'good practices' in science communication and website usability.

The COVID-19 situation also led to delay in results from the national and regional assessments and updates on the regional studies. The A-teams had to postpone the stakeholder workshops that were essential in the research timeline. The analysis and reporting on the results of the national studies was postponed; thereby delaying the design of the format for presenting the results, content editing and including the results in the Impacts Explorer. The Wageningen Base Team responded by frequent communication with the A-teams to support them as much as possible in early delivery.

6.5 Survey Approaches

The process of collecting data took place during restrictions imposed to contain the Covid-19 pandemic in the three countries. The project team collected all data remotely, by telephone or the internet. The situation is likely to have affected data collection in a number of ways. Most participants could not come to their offices. Individuals often have worse access to internet, phone connection, and general working conditions at home than at the office. They may not be able to devote as much time and attention in the presence of competing responsibilities and uses of space at home as they may have been able to in the office. The situation may have reduced participation in the study and it may have particularly impeded participation by those who do not have access to the internet at home and whose living conditions are generally more modest.

7 Revisiting Objectives

7.1 Ghana

The Ghana A-Team built on the prior AgMIP DFID work to increase national stakeholder capacity to develop evidence-based NAPs and related investments through the use of science-based RIA products. The Ghana A-Team also completed the regional RIA work that was not possible to finish during AgMIP DFID so as to also be able to advance the CLARE objectives to link regional and national scales of study. Two main platforms were used to achieve this aim namely; webinars and workshops.

The AgMIP A-Teams Project Coordination organized a series of webinars (bi-weekly) which were interactive and was aimed at keeping track with the pace of work. This also served as a platform where knowledge was shared among A-Team and Base-Team and hence served as an avenue of capacity building particularly for the A-Teams.

There were other virtual meetings that served as capacity building for A-Team members. Firstly, zoom meetings on RAPs development, quantification and review of RAP narratives was very essential capacity building efforts. Effective design of survey instruments was another subject that was addressed through virtual meeting.

Workshop engagement with stakeholders also serve as an interactive platform for learning and knowledge exchange thereby resulting in capacity building for both A-Team members and stakeholders. The forward looking scenario building exercises that were carried out also contributed to building of the capacity of many of the stakeholders in this area while enhancing the capacity of those of them that were familiar with scenario building.

Two information products (a policy brief and an information brief, see also Annex 13.2) were produced by the Ghana A-Team. The A-Team has increased its capacity to co-develop information products of value to national and international stakeholders

7.2 Senegal

Among intended goals, AgMIP A-Teams Project aimed at improving previous AgMIP work by updating RAPs based on existing policy documents, current socioeconomic context and priorities, and refining findings related to future climate change impacts. Regarding RAPs, the objective was fully achieved with a continuous engagement of stakeholders in the development process. The different workshops and informal events held, when coupled with follow-on exchange, contributed to stakeholders being able to co-design the different pathways. In each scenario, stakeholders identified key prerequisites (in terms of policies to implement) to achieve the path. This approach of stakeholder engagement also built their capacities to co-develop forward-looking scenarios.

With stakeholders, a baseline for monitoring & evaluation of the project was investigated in the context of NAP processes, as proposed. This analysis turned out to be especially relevant because it highlighted the main vulnerabilities in the agricultural sector, and how research in the CLARE Program in particular, could support ongoing NAPs processes with relevant information to guide climate action.

This resulted in updated research questions on future climate change impacts and adaptation impacts for contrasting RAPs. The findings have been translated into products accessible to, and co-owned by, stakeholders. They include policy-briefs, Info-briefs, and updates to the web accessible Impact Explorer. Co-owned and developed with stakeholders, they provide further insights about how longer term societal objectives can shape paths, which in turn generate the most appreciable findings in the context of climate change and adaptation packages proposed.

7.3 Zimbabwe

The focus of the AgMIP A-Teams Project in Zimbabwe was enhancing the research links between the A-Team composed of international, national and regional organizations and national and regional experts and stakeholders, in order to influence agricultural adaptation decisions though national plans and processes. The engagements built on prior AgMIP work that focused on regional-scale assessments.

The rationale for research to inform national policy processes was enhanced by a baseline assessment, which included consultations with a wide range of national and regional representatives involved in agriculture and climate change adaptation planning. The A-team built capacity on the co-design, interpretation and use of scenarios and impact assessments, including interactions with stakeholders on their use as decision support tools. A series of workshops and webinars were designed as learning events for the A-team to engage with representatives from diverse government organizations and development agencies, as well as research and extension services.

In this process, national and regional scenarios and impacts results were updated, based on recent policy priorities. They were validated through the multi-disciplinary audience of technical experts that perform key functions in national level policy and decision processes. Emanating research - policy gaps were identified, as were structures that the country can build on to strengthen climate change adaptation processes. The revision and reflection of research outputs with national and regional experts generated understanding of the complexities and plausible causalities that determine future socio-economic and climate conditions. The engagement brought forward specific suggestions for a road map on how these approaches and tools could be made available – and what requirements would need to be addressed – to inform climate adaptation and mitigation plans, programs and actions. The contributions were integrated into a policy brief illustrating the conceptualization of research informed policy and decision making for climate adaptation.

A strong argument was raised for the need to capacitate a wider range of national researchers in the application of the various research tools to inform decisions at scale, and to support feedback between local level applications and national policy processes. At the same time, capacity building among policy makers is also needed to ensure a firm understanding of the tools and their potential contributions (and limitations) to adequately and effectively support a role for research in national climate change adaptation planning and decision processes.

Visibility among stakeholders was compromised due to restricted engagement processes and delayed delivery of outputs. A series of presentations, co-authored by the multi-disciplinary team and representing the involved national research organizations, were targeted to national and international audiences. This was critical for raising awareness and justifying the basis for research in policy making processes. For national actors to further own and apply the AgMIP forward-looking methods, tools, protocols and data need to be documented and made available. This will support the accountability of scientists to policy and decision makers, strengthening the research-informed adaptation processes.

Multiple entry points were identified by the A-team as to how research-based outputs can contribute to creating an enabling context for sustainable agricultural development under climate change. These need to be followed up beyond the life time of the AgMIP A-Teams Project. Efforts are being made to raise funds through national programs and international applications to support continuity as well as expansion of the partnerships among research, policy and development agencies.

7.4 Impacts Explorer

The objectives for the Impacts Explorer were: (a) Adding selected RIA results; (b) Expanding the relevance of the AgMIP Impacts Explorer to global users and enhance the ability of in-region stakeholders to place their challenges in the global context through the addition of critical global data sets from AgMIP modeling activities; and, (c) Improving Impacts Explorer user experiences, including through the development of an Adaptation Support Tool.

Regarding (a), new pages are being added to include results from Ghana, Senegal and Zimbabwe national and regional assessments, and thus to support understanding the relation between national policies and regional farming systems and contexts. Together with the A-Teams, formats to present the RAPs were designed.

For (b), a new global map viewer was added, including the maps produced by the AgMIP Global Gridded Crop Model Intercomparison project, and the maps produced by the IFPRI IMPACT Model.

Regarding general improvements and adaptation support (c): version 2.0 of the AgMIP Impacts Explorer is designed to meet the information needs of users involved in agricultural adaptation planning and to make research results better accessible and understandable. It matches the setup of well-known adaptation support platforms supported by international organizations in climate change adaptation. The design is from a requirements analysis described in Section 5.

Updates are being made to the regional studies from AgMIP DFID, regarding both content and presentation of the results, in close collaboration with the teams. For Navrongo, Ghana a new page on recent RIA findings is being included. The impacts dashboard has been extended with links to the national studies.

Following consultation with the coordinators of the national studies, a map viewer has been developed to provide access to the maps at national scale. This map viewer is integrated in the national studies result pages.

The Methodology section is updated and more user friendly; texts are more compact and avoid technical vocabulary where possible. Results of the studies are linked to the Methodology section, so interested readers can explore the methodological background.

Evaluations of the Impacts Explorer indicated that the Data Explorer is less effective than the other components. Therefore, it has not been updated; however, it will remain available for use and may be advanced in a later stage.

8 Gender and Social Inclusion

8.1 Ghana

The Ghana A Team is comprised of four (4) members, three of which are male and one female, with the female also providing the role as Leader, having not only had previous leadership and knowledge roles in AgMIP projects, but also having research administrative experience, including as Head of a University Research Centre for many years.

With regard to stakeholders, 30% or more were female, several of whom brought important gender dimensions to the discourse. Additionally, expertise was invited from the Women in Agricultural Development (WIAD), a Unit of the Ministry of Food and Agriculture, to make presentations at the Stakeholder meetings. Though women constitute a large proportion of the agrarian community in Ghana, the crops (mainly vegetable) they produce are often considered “secondary” and not given due attention in climate and adaptation discussions. Even in this current project, the focus was on major cereals and legumes. The climate change impact on vegetables was not explicitly modelled. It would be useful to expand the scope of the linked biophysical and socio-economic surveys to include a broader spectrum of crops, especially those that are regarded as “womens’ crops” in a future study.

Given that the project involved the interaction with human subjects, the proposal had to satisfy the ethical clearance regulations in place at the University of Ghana. Consent of each stakeholder interviewed or involved in the survey was obtained prior to interview and the administering of the online survey.

8.2 Senegal

Gender is an important component of this project. The research team was led by a woman, as was the development of policy- and info-briefs for more general communication of findings. During interactions with stakeholders, we ensured women were significantly represented and actively participating in these sessions. As such, the project inception meeting with stakeholders was composed by 25% of women. More than 36% of the participants during the first workshop were women, as were 28% in the second workshop.

We also included a gender analysis while co-designing agricultural pathways with stakeholders. We examined how and to what extent gender equality will evolve across the RAPs. Examination of the SD pathway, for instance, shows that a national strategy on gender equality and equity will have positive impacts, contributing to enforced reforms for women to have better access to land and means to sustain a farm system, including a household.

8.3 Zimbabwe

At the national level, the gender action plan caters to gender and social inclusion as part of CSA. The A-team supported gender and social inclusion in various ways, including as part of the research and engagement approach, in feedback with participants/experts and stakeholders, and in team efforts.

1. **Women representation:** Women participation among national and regional level participants/experts and stakeholders was encouraged. Strong links were built to the Ministry of Gender, Small and Medium Enterprises, which provided active representation and support at the workshops. This ensured gender perspectives in the set-up of research tools, interpretation of results and links for future engagements. Women participation in workshops varied between 13 and 27%; women participation in the A-Team was 25%. The A-Team is led by a woman, and two scientists have explicit gender qualifications. About 40% of households at the study sites are female headed.

2. **Gender and inclusiveness in the analyses**: Workshop participants highlighted that research to support climate policies and action must consider gender, as men and women are differently affected by climate change. Research should help to inform how women farmers can participate in climate smart options, considering the barriers, risks and trade-offs involved in the uptake of research-informed recommendations. The access to and use of ICT in managing agricultural activities is still limited, especially for women. Investment in gender-sensitive human and institutional capacity development is critical as a component of sustainable agricultural production systems. This involves a paradigm shift towards working with women as change makers in agriculture.

3. **Gender and inclusiveness in national and regional RAPs**: The design of national and regional RAPs includes qualitative statements on policy implications as well as implementation outcomes, with regards to the importance of promoting equity and equality, ownership, decision making and empowerment through in access to and control over resources, information, finance, capacity development and market participation. Gender responsiveness is a strong component in SD and related adaptation packages, to

contribute to more effective poverty reduction and equity, under current conditions and in a future with climate change.

4. **A-Team experience on gender and inclusiveness:** A-Team members have published on gendered impacts of climate change, and the role of women in climate resilient livelihoods. This has informed the regional scenarios and adaptation packages, to ensure that policy support and interventions are gender smart. The SD pathway promotes the diversification of production systems and market offtake of crops and livestock. Benefits to women are needed in recognition of their critical roles in agriculture, business, and as providers of household nutrition.

8.4. Impacts Explorer

The Wageningen team consists of a project leader, financial support and 4 developers/ designers, for an overall roster of 4 females and 4 males. For the requirements analysis and testing for the Impacts Explorer, representatives of the target user and stakeholder group are selected; within that group gender, age, and function are considered. Further, In the selection and use of materials such as photographs of agricultural areas and stakeholders, we strive towards a fair and balanced representation.

9 Uptake

In this section, we touch upon processes to facilitate stakeholder demand and/or endorsement as experienced during the project, including not only the efforts, but also the challenges and successes resulting in uptake and co-ownership of research results.

9.1 Ghana

Developing policy briefs

A major activity of this project was the development of policy briefs. The process began with stakeholder mapping to identify the various groups of actors in the Climate Change adaptation planning landscape that influence policy decision making. Representatives from the stakeholder groups were interviewed to test a semi – structured questionnaire intended to be used as a guide. Topics discussed centered on: (a) challenges faced by stakeholders in Climate Change adaptation planning, (b) successes, and (c) the research needs of stakeholders (see, e.g., Figure 9.1.1).

The responses from the interviews provided a basis to develop the full questionnaire which was administered to about 60 persons selected from the categories identified in the stakeholder map. The questionnaire was administered using the SurveyMonkey online tool. A stakeholder engagement activity was subsequently organized where results of the survey were shared and discussed.

Factors that handicap the linkage between science and policy were also discussed and possible ways to bridge gaps were enumerated.

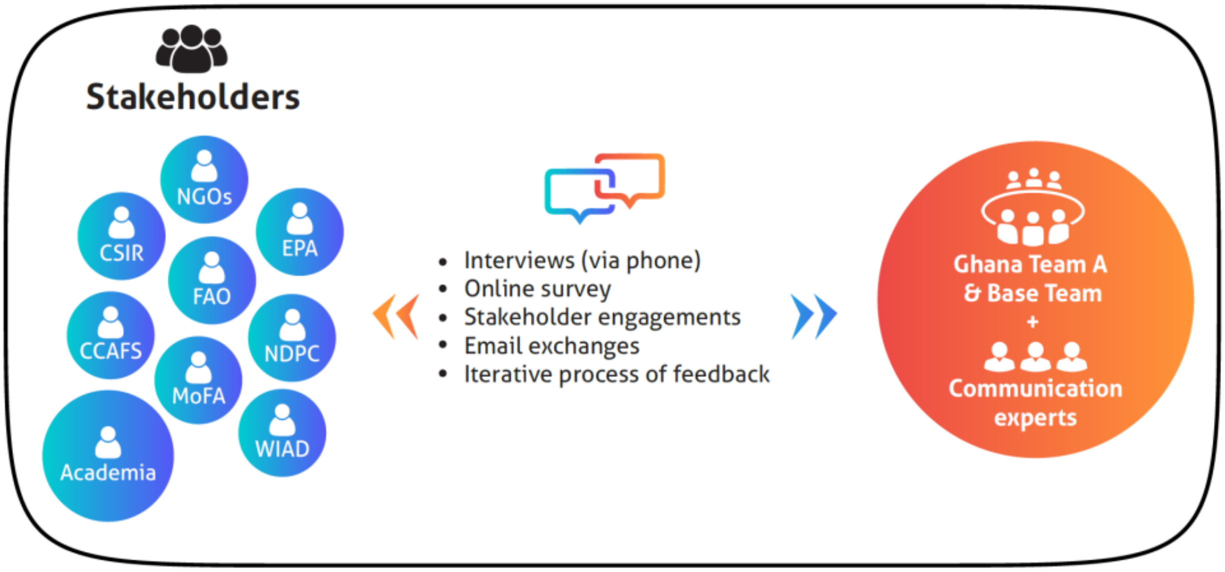


Figure 9.1.1 Illustration of iterative processes leading to development of policy brief

The Ghana A Team subsequently organized another workshop for selected number of stakeholders to discuss the structure of potential policy brief that targets decision makers. The composition of the stakeholders was limited to: (i) 2 persons from the Climate Change desk of the Ministry of Food and Agriculture, (ii) A deputy director from Environmental Protection Agency, Ghana (Coordinating Unit of National Climate Change reporting), (iii) A senior Lecturer from University of Ghana who is also a lead author in WGI of 6th IPCC report and (iv) A Scientist from the CCAFS platform, an instrumental organization in Climate Change discourse in Ghana.

With these 5 stakeholders, a first draft of the policy brief was reviewed based on the outcomes of the online survey, interviews, stakeholder engagements as well as their professional knowledge in the field of climate change and agriculture. The draft policy brief was then circulated to members of the Base Team for their feedback and then to the communication specialist to develop the policy brief. The output from the communication specialist was shared among the A-Team members, selected persons in the Base Team, as well as the 5 stakeholders, for their feedback. This was an iterative process to finalize the policy brief. Some of the stakeholders requested their logos be included in the policy brief due to the level of contributions they made. The request to co-author the briefs has been accepted, as it means they are comfortable to be associated with, or to co-own the content.

Testimonials

- *Environmental Protection Agency, (EPA)*

Dr. Antwi-Boasiako Amoah**:** I am a Deputy Director at the Environmental Protection Agency, (EPA) Ghana, and I am in charge of Climate Vulnerabilities and Adaptation.

My exposure to the AgMIP RIA tool educated me on need to adopt such a forward-looking approach t to inform policy and investment decision on the appropriate adaptation strategies to promote, help in the identification of potential vulnerable groups under climate change, and provide evidence for prioritization and budgeting, with respect to policy formulation and implementation. Currently, the National Adaptation Plan (NAPs) process is at a stage where we need to assess the economic viability of the list of adaptation strategies available. I see this methodology to be very vital to this process. I will also recommend capacity building in RIA for other scientists and stakeholders beyond the project team to enable up-scaling the approach to include other farming systems in the country. An area I will like to see this methodology extended to is climate change mitigation, beyond adaptation. This is an area where information is grossly inadequate. The Environmental Protection Agency (EPA) would be willing to share results of this study and other materials such as the Info and Policy briefs on our web site as we participated in co-producing them.

- *Ministry of Food and Agriculture (MoFA)*

Mr, Kingsley Kwako Amoako: I am a Deputy Director and Head of Environment and Climate Unit of the Ministry of Food and Agriculture, (MOFA).

We find the AgMIP (RIA) methodology useful to support our work in climate change impact and adaptation assessments within the agricultural sector in Ghana. Hence, we will like to see the methodology extended to other farming systems that contribute to the food basket in Ghana. We are willing to partner the AgMIP Ghana team in a future study and also request for capacity building in the use and interpretation of the outputs of the methodology. On priority research areas to contribute to the climate change adaptation discourse at the national level, more studies are required to assess the economic feasibility of Climate Smart technologies and practices. Additionally, studies on up-scaling and improving traditional farming practices, leveraging technology and new knowledge to support the climate change adaptation planning process, are required. We are interested in hosting the Impact Explorer on our website but we are currently technically challenged. Once we overcome the challenges, this will be done. MoFA is interested in adding our logo on the Info and Policy briefs to which we have contributed as co-producers.

- *Animal Research Institute (ARS)*

Mr. Vincent A. Botchway: I am a Senior Scientist at the Animal Research Institute, of the Council for Scientific and Industrial Research as well as the Secretary to the Climate Change Agriculture and Food Security (CCAFS)-Platform in Ghana.

I find the AgMIP methodology to be very interesting and very useful in contributing to the NAP processes since it generates data that is essential to support decision making process. I would like to see the methodology extended to other farming systems in areas such as the Coastal Savannah and Transitional zones of Ghana as well as crop-livestock integration. We (CCAFS) would like an improvement in terms of the ability of the methodology to factor in the multiple benefits derived from a crops as food and feed source to justify the potential use of the methodology in both the major and minor growing seasons. Up-scaling the use of the method would require will require capacity building in the use of the tools for both scientists and policy makers. We therefore recommend capacity building for scientists and stakeholders beyond the AgMIP Team and we are willing to partner the AgMIP Ghana Team in a future study. A priority research area to contribute to the climate change adaptation discourse at the national level is "Assessment of agro-ecological based Climate Change Adaptation and Mitigation Potential of Crop-livestock Integrated farming systems".

9.2 Senegal

An essential strand of A-Team work is to identify, from a broader prospect, how climate researchers can collaborate in specific ways with policymakers to share information highly relevant to current and future policies on adaptation. This work is summarized in an info-brief with key recommendations to achieve this goal in the Senegalese framework. The recommendations are possible owing to the results of several interactions we had with stakeholders, including a collaborative review of main policies plans (NDcs, Emerging Senegal Plan, Senegals' main agricultural development plan (PRACAS), etc.).

The baseline survey for monitoring and evaluation greatly aided our discussions with 10 national key stakeholders about ongoing NAPs on climate change for the agricultural sector. These discussions were essential to understanding the main obstacles to NAP advancement, the key priorities policies should focus on, and how science could play a pivotal role in this agenda.

The team had also organized a workshop to present preliminary findings of the project. This was an opportunity to examine the relevance of those findings, and to engage in interactive discussions on how the AgMIP A-Teams Project methods and findings could be improved to develop and implement relevant adaptation policies.

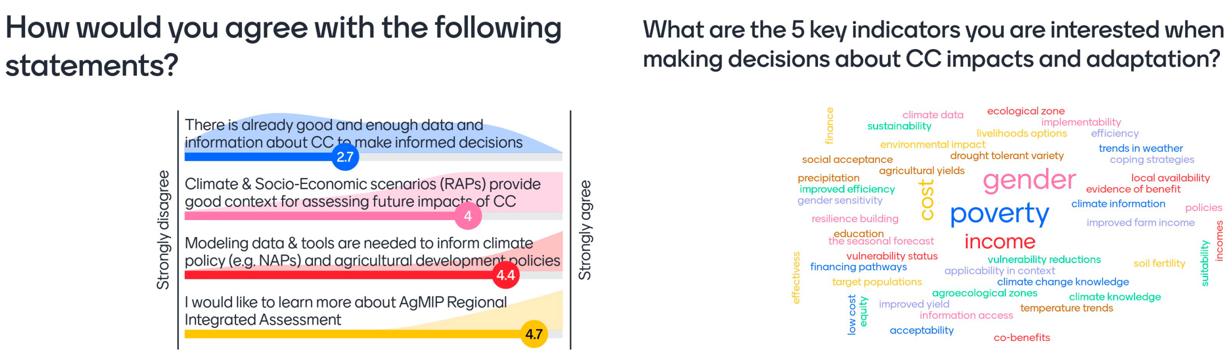
These outputs (baseline survey, workshop reports, project findings, informal sessions with stakeholders, etc.) were used while drafting the info-brief (See also Annex 13.2). The brief is intended to show that AgMIP's forward looking research methods specifically seek the incorporation of stakeholder inputs, including policymakers who are keen to understand the possible implications of well-intentioned interventions. There is a wide interest in assessing communities with vulnerability to climate change. However, the current lack of available data to fully explore implications and likely results is a critical concern raised by stakeholders. Hence, a well-organized effort for the acquisition of specific data and evidence, especially at the local level, is greatly needed to prevent misalignment among NAPs and implemented actions at the local level. Further, for a better understanding of findings, research communication should be accessible in a language accessible and useful to a range of stakeholders. The latter also stressed the need to build capacities among national researchers, policymakers, and central statistics offices (CSOs), to incorporate results based on the AgMIP tools applied to explore new evidence (by researchers) from which further actions can be investigated based on the findings (by policymakers).

Finally, throughout the national workshop that was held, the team was able to raise interest and convince a set of stakeholders to take important actions. Among those actions was the Ministry of Environment decision to organize a special meeting with different research organizations and projects in climate change adaptation. The objective will be to identify how we can break silos and work together to avoid research duplications and learn from each other.

In addition, the A-Team created 2 videos that will be shared via the Impacts Explorer.

9.3 Zimbabwe

The demand for the AgMIP's forward looking approaches, tools, outputs and interest in partnership for their wider application, was clearly confirmed at interactive workshops (Figures 9.3.1).



Figures 9.3.1 Feedback at multi-stakeholder review workshop on relevance of simulation modeling and climate change impact and adaptation decisions

Important elements for creating stakeholder interest include:

- Helping stakeholders understand that they have a role in contributing to ongoing processes, that serves the purpose of reducing poverty by improving climate change adaptation, integrating multi-disciplinary perspectives;
- Creating ownership and buy in with stakeholders, by reviewing scenarios and impact simulations for particular farming systems together, to identify policy gaps and develop policy messages; and,
- Developing a road map with the stakeholders to establish how the AgMIP products can be taken further, through which channels, and what this would require.

A policy brief on “*Working towards climate resilient agricultural systems in Zimbabwe*” (see also Annex 13.2) addresses an audience of middle to high level government decision makers, including technically influential experts as well as research and academic institutions and development partners, and the Zimbabwe Research Council. It is a product of an interactive process, which was drafted through multiple A-Team interactions, making use of stakeholder reflections at workshops.

A second policy brief on “*Climate Change and adaptation impacts in mixed crop livestock systems in south west Zimbabwe*” illustrates simulation results for mixed livestock systems as important farming system, and policy messages generated through expert feedback on the simulation results and interpretation (see also Annex 13.2)

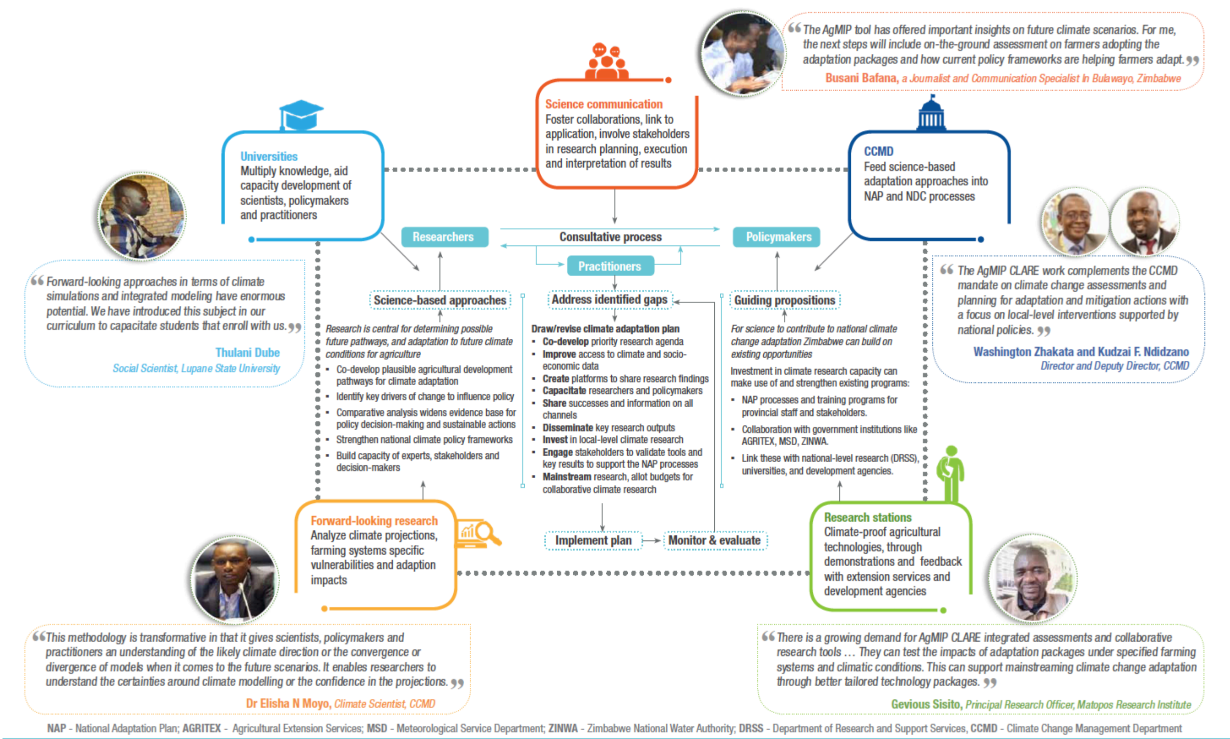


Figure 9.3.2. Conceptual diagram on how science-based approaches can support climate change adaptation in agriculture in Zimbabwe.

The briefs were developed with the following approach (see also Figure 9.3.2):

1. Identifying the focal area: The baseline report was consulted, as were inputs from stakeholders on critical challenges and gaps in climate change planning and action, to define the focus that the policy brief should speak to. Enhancing science-policy collaboration was identified as the key issue, for research-based climate change adaptation to support agricultural systems transformation.
2. Building the body: The brief builds on material developed during the interactive workshops, at which representatives from diverse policy relevant organizations participated, different

government departments (climate change, crops, livestock, economics, extension, gender), researchers (scientists involved in NAP and NDC processes, as well as development agencies with a climate change focus.

3. Final revision: The final draft policy brief, including the audience that it is supposed to address, was revised with few selected policy and decision makers. This ensured that the focus, the flows of arguments, and the language corresponded to current policy issues. The dissemination strategy was also verified.
4. Dissemination: The dissemination strategy was developed by workshop participants. The policy briefs are to be presented at interactive webinars hosted by the Climate Change Management Department in collaboration with the Department of Research and Specialists Services, having wide stakeholder representation. Subsequently the briefs - as well as Impacts Explorer links - will be shared for posting through various websites, incl. Climate Change Management Department, Department of Research and Specialists Services, A-Team partners and other media. ICRISAT will promote the policy briefs along with other publications at international forums.

Diverse statements confirmed relevance and efforts to bring the scenarios and simulation applications into use.

Fostering Stakeholder Demand

The following requests were raised by stakeholders at the workshops

- There is need to bridge the gap between policy and what is happening on the ground so that policy, science and implementing strategies speak to the realities in terms of climate change adaptation. This means paying attention to likely climate change impacts under particular conditions. Scenarios give an indication what impact could be, as well as the potential of multiple challenges superimposed, affecting agricultural growth.
- The information resulting from the scenarios we modeled should be availed to policy makers, to consider and understand the outcomes of policies. Often, policies are made without considering outcomes of long-term benefits and impacts. If policy makers can be enlightened to see the outcomes of their policies, they would make different policies than they are developing today.
- The crop livestock situation in Nkayi shows high potential to continuously be improved, in terms of suitable crop varieties, and improving productivity through multiple interventions, to improve overall farm net returns. The tools help to identify gaps for research in terms of adaptation and what it means for policy decisions. We hope to follow up on the issues shared, especially crop diversification, legume promotion, and the selling fodder by those who don’t have livestock.
- We can look at benefits from using the models, that apply to our various departments. We can use them to develop funding proposals, for something that enables us to do something on climate adaption. The modeling has requirements that are complex, but if we have the expertise, we can achieve more.
- There is need for intensive training on the tools, through more workshops, conferences, and scholarships.

- Funding opportunities for capacity development can be explored together, e.g. through CCMD, GCF, NAP.
- Policy briefs should be endorsed through the respective Ministries, and promoted through the Ministries websites.
- A series of webinars should be held, showcasing the policy briefs and simulation results, to widen awareness and create wider buy-in.
- A specific policy dialogue should be held at national level to review policy messages and their implications.

Enabling Endorsement

The following are individual statements that illustrate commitment for uptake

- Washington Zhakata, Director Climate Change Department: Evidence and information generated from the AgMIP A-Teams Project can feed into the on-going NAP and NDC processes. As the implementation of the NDC and NAP is rolled out, the findings of the AgMIP A-Teams will become very useful and relevant in informing local level adaptation measures building on district level studies conducted by the project such as Nkayi. There is need for concept note development to apply the approach to other agricultural systems. The CCMD can the facilitate the submission to relevant funding mechanisms, including GCF, national budgets and international agencies.
- Thulani Dube, Social Scientist: Lupane State University has established a new MSC program on climate change and sustainable development as part of a SADC funded program to mainstream Climate change and adaptation. The University introduced the AgMIP RIA approach as component in its MSc curriculum. AgMIP CLARE, through capacity development on simulation modeling, running through the MSc program, can support a better understanding of vulnerability to climate change and adaptation strategies contributing to sustainable agriculture.
- Gevious Sisito: Matopos Research Institute has been identified as innovation centre to promote climate smart technologies/interventions for resilience building through UNDP-GCF together with Government of Zimbabwe. The department will utilise AgMIP A-Teams Project tools and approaches for assessment of adaptation across districts country-wide where the innovation centres for testing adaptation are being implemented. AgMIP TOA-MD capacity building provided opportunities for supporting the Botswana NAP, funded by UNDP-Botswana, and for technical backstopping on applying the tools to Agro-Forestry Systems in Zambia, through Provincial Agricultural Coordination offices.
- Elisha N Moyo, Climate Scientist: The climate tools were found useful to understand and investigate the historical and future climate dynamics in Zimbabwe, to select representative models for use analysis of climate projections and investigation of the impact of climate change on maize production. There is a strong appeal to enable national staff to be able to access and analyse future climates scenarios and climate projections. This gives scientists, policymaker's and practitioners an understanding of the likely climate direction or the convergence or divergence of models when it comes to the future scenarios. It also enables researchers to understand the certainties around climate modelling or the confidence in the

projections which could be carried to the impact studies. The knowledge gained from AgMIP was applied in contributing towards reviewing the climate model results of the National Water Resource Master Plan development. In providing the methodologies, tools and data, this addresses challenges that come with the monopoly associated with climate modelling development within the sub region.

- Busani Bafana, Journalist: I could not have been more prepared to apply the principle of effective communication when I participated in the revision of a policy brief on assessing and highlighting the AgMIP tools. I realize the strength of identifying messages in knowledge products for public information, and in this case, policy advocacy. Policy makers are important actors in the development narrative. Building capacity of all stakeholders in promoting the AgMIP A-Teams Project is an important consideration. Researchers can help build the capacity of policy makers and in my case, of the media in understanding of the AgMIP tools. I would like to document the engagement processes with farmers/policy makers in the context of the promotion of the AgMIP Tools in which modelling has been done.

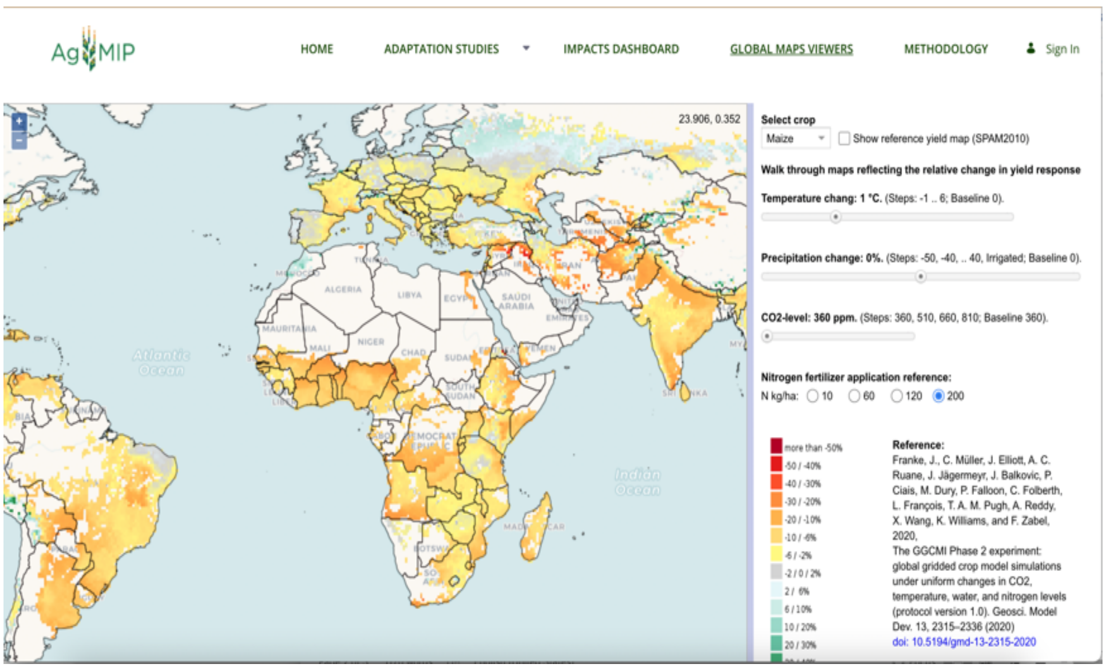
9.4 Impacts Explorer

- The AgMIP A-Teams Project findings are incorporated in the Impacts Explorer in several ways. The findings of previous AgMIP DFID phases have been updated with additional results, edited, and included in the section with regional studies for Navrongo, Nioro, and Nkayi.
- The new regional study template aims at presenting the results from the scientific modelling and stakeholder interactions in a manner that matches IE users' information needs and follows well-known steps in adaptation planning.
- In the descriptions, the specific features of the AgMIP methodology are placed in a broader context of phases in policy design, implementation, and evaluation. These are also linked to explanations in the Methodology section. The descriptions are brief, to support online reading, and aimed at an audience including non-experts. Several pages include thumbnails and links from which more extensive descriptions of the results, reports, or policy briefs, may be opened.
- Findings from the AgMIP A-Teams Project that are specifically related to questions on national adaptation are included in the national and regional assessments for Ghana, Senegal, and Zimbabwe. For Ghana and Zimbabwe, tailored map viewers are included to present results from crop (maize) studies, respectively, including climate modeling and similarity analysis.
- Stakeholder testimonials feature important messages from the studies and bring the importance of the AgMIP methodology and the value of results for adaptation and mitigation planning, to the foreground.
- Main indicators resulting from, and summarizing, the regional and national studies are presented in the Impacts Dashboard. The dashboard links to the descriptions in the studies.

The dashboard can be viewed in relation to a map viewer that includes extensive data sets on crops, climate, and economic conditions.

- To provide the context of the regional and national studies, and to meet information demands from funders and other organizations with a global interest, a global maps viewer has been developed and included in the Impacts Explorer to supports the viewing of maps produced in the AgMIP GGCMI project and IFPRI Impact model. The maps show long-term average crop yield changes for maize, wheat, rice, and soybean in response to systematic local changes in temperature, precipitation, CO_2 concentration and fertilizer application. For a broader and longer-term picture of the food system, IFPRI's IMPACT model is used to project the future of key indicators at the national level for all countries.

Map produced by the AgMIP GGCMI Project (Impacts Explorer screenshot)



Navrongo Regional study (Impacts Explorer screenshot)

What is in stall for Crop Production at Navrongo, Ghana under Future Climate Conditions ?

The full description of the case study can be downloaded here (pdf thumbnail)

Navrongo is located in a semi-arid region in Ghana and is characterized by a low-input rain-fed smallholder agricultural system. The dominant cropping system is cereal-legume based with the main crops being maize, sorghum, millet, peanut and cowpea. Livestock plays an important role in the farming system with the manure used as fertilizer while crop residues also serve as an important feed source.

CURRENT FARMING SYSTEM

Low input system
Rain-fed
Maize, sorghum, peanut

Shallow soils
Low soil fertility
Semi-arid region

CLIMATE 2050s

Projected temperatures increase by between 1.4 to 2.3°C

Variable rainfall amounts with a potential decrease of up to 12% in number of rainy days

IMPACTS

Maize as grown today is vulnerable to climate change

Sorghum is less vulnerable to climate change

Peanut benefits from climate change due to CO_2 fertilization

VULNERABILITY 2050s

Between 48 to 59% of households would be vulnerable to impacts of climate change under current production system.

Under future production systems, about 36 to 48% of households will be vulnerable.

ADAPTATIONS

Between 48 and 56% of farmers adopt the use of heat tolerant varieties resulting in about 22% reduction in poverty.

- Identify challenges
- Assess vulnerability
- Develop adaptation options
- Take action
- Evaluate and review

Additional info

References to scientific papers, websites and other relevant resources.

Identify challenges

Link to more explanation

Figure 1: Map of West Africa, showing Ghana and Navrongo

Agriculture in Navrongo, Ghana (Figure 1), is predominantly characterized by low-input rain-

10 Additional Insights

10.1 Ghana

For research to effectively result in impact, it has to be demand driven. To this end, as part of this study, research needs in the climate change adaptation planning were solicited using an online survey. The key issues that emerged from the survey show that, stakeholders need;

(i) To understand which adaptation strategies are effective for whom, under what conditions.
(ii) An understanding of the cost of adaptation and to make the case for investment in adaptation strategies, under different conditions.
(iii) Information to guide risk management and adaptation decisions in specific contexts.
(iv) Climate information services that can guide decisions, especially farmers' decisions.
(v) High-quality seasonal predictions and communication of variables that farmers need to make decisions on the farming activities, and information that improves linkages between climate variables and decisions

The Ghana A-Team aims to developing proposals with some of the stakeholders to address some of the above issues that they indicated as critical. Another avenue to be employed in a future study is a strong emphasis of the gender dimension of climate change and how the more vulnerable population can be supported to mitigate climate change effects. It is acknowledged that the Ghana A-Team's participation in this project has been a great learning curve, which is necessary for a broader look at the climate change issue, and it is desirable to continue the collaboration in this project. Yet, we must also indicate the major challenge with regard to the need for additional expertise, especially with respect to socio-economic modelling. Future collaboration will give special attention to capacity building. The team, in collaboration with other stakeholders, will be embarking on a proposal writing as to solicit funds to further enhance capacity of the team members and other stakeholders on the use of these forward-looking tools as well their utilization to scale up the methodology to other important farming systems. Proposals will target the above needs enumerated by stakeholders.

10.2 Senegal

In terms of research, there is a need to do vulnerability studies to climate change relevant at the national scale: several research projects were carried out to explore vulnerabilities of local communities to climate change. However, they are very limited as they are case studies and do not inform vulnerability at the national level and its heterogeneity across agro-ecological zones. Besides, stakeholders stress the need to update agro-climate zones profiles and assess which crop varieties and adaptation strategies are mostly suitable within each zone. Another valuable research strand refers to the assessement of the most effective interventions or adaptation strategies to decrease farmers' vulnerability to climate change. In addition, considering the importance of rice in national consumption patternsAssess climate change impacts on other relevant crops such as rice.

Beyond research, several activities could have sizeable benefits for the stakeholders. This is the case for national researchers' capacity building in tools and methods used by AgMIP so as they can undertake/replicate priority research projects at the national and regional scales. Building stakeholders (policymakers, grassroot organizations, donors) capacities in forward-looking scenarios would also raise their awareness in considering which changes and policies are needed to follow a desired pathway.

10.3 Zimbabwe

There is need to widen the AgMIP A-Team Project applications supporting policy development towards societal/national sustainable development goals and visions, e.g. through the NAP and other country driven climate action and processes, in-country capacity development and extending the application to other farming systems. Actions include:

- Improving co-developed and forward-looking research methods, including ways to prioritize, target, and scale the impacts of agricultural research and food system interventions in the drylands;
- Including social, cultural and institutional drivers and how they affect the distribution of socio-economic and environmental benefits and trade-offs for particular local contexts and farm types;
- Assesing the likely benefits and trade-offs of interventions in diverse farming contexts and farm types, to inform national level policy, research for development priorities and food security programs;
- Measuring the cost-effectiveness, and rates of returns on, public investments in agricultural research and development;
- Advancing gender and nutrition components and how they relate to climate impacts;
- Closing policy practice gaps by supporting evidence-based decision-making at various integration levels and strategic communications; and
- Supporting multi-disciplinary community of practice and capacity development for forward-looking research methods and impact assessment.

10.4 Impacts Explorer

Through AgMIP CLARE a new set up of the AgMIP IE was established, with a closer connection to the way of working of primary users, such as regional or national policy makers or data analysts at farmer cooperatives or agri-supply chain companies. A necessary update to the AgMIP IE is to extend it to more countries and regions for the deeper analysis, ideally across continents, so that with the same methodology many more users can be reached. Here a multi-lingual AgMIP IE would become important and needs to be clearly planned. Now that new version of the AgMIP IE is there, more user targeted evaluation is required to see whether it is usable, if the user finds the information they need, and what additional insights and functionality can be offered to support their work. Stakeholder involvement and collaboration in developing such extensions and content, is key. The IE team supports a user-centered design perspective in designing tools, to improve accessibility and usability of data for decision support in cross-scale and transdisciplinary contexts. Future efforts will include methods and techniques to design and implement platforms for knowledge sharing and co-learning in the Science, Policy and Practice interface, in different cultural contexts.

A second important step is to better connect the different parts of the AgMIP IE from a functional point of view, as the Global Maps viewer give an understanding of climate change hotspots and impacts, that could be translated to national insights, which in turn have an impact on the regional level. The AgMIP IE will not solve how this can be linked from a conceptual point of view but needs to visualize the connections well for users to understand the logic and the interpretation of results.

Also new functionality can be designed or improved for new user groups, as the users acting at global level have been identified, for example, climate change advisers at donor organizations, or data analysts at large corporates, or experts at multi-lateral organizations, but the user requirements could not be adequately captured as part of AgMIP CLARE and they might benefit from the especially the global maps viewer and the maps there. This requires more analysis and steps and potentially setting up a Global Adaptation Support Tool for Agriculture, based on the global maps viewer, and what is captured as a method in the regional pages.

Finally, as a new direction, many existing adaptation support tools are primarily data and knowledge repositories for policy makers and scientists. In AgMIP stakeholder meetings, A-team project members and engaged stakeholders have expressed the importance of knowledge sharing and tools to support capacity building activities. To support knowledge sharing, extensions for a tool such as the IE may consist of for instance interactive capacity building modules and a functionality to allow members to connect. To enable stakeholder (co-)learning on agricultural adaptation to climate change, teaching materials can be developed may be hosted on the IE platform.

11 Recommendations and Feedback

11.1 Ghana

Given that the AgMIP method currently focuses on the social application phase, a strong expertise in socio-economic modelling aspects is essential. For future collaboration, we request the inclusion of training for a student for Masters and possibly through to Ph. D level in in Trade-off Analysis, and other AgMIP tools. This would help build the critical mass of researchers to further demonstrate the use of this forward-looking methodology and to become a backbone of a future projects. Additional scientists need to be recruited to strengthen and enhance the effectiveness of the A-Team and to also help make more impact in the climate change adaptation planning discourse in Ghana. The one-and-a-half-year duration of the project limited the number of interactions as well as the depth of discussion of results with stakeholders to solicit more feedback. Potential funding for another phase should consider a longer duration and higher budget so as to achieve far more reaching impact.

11.2 Senegal

Efforts are underway to transform the lessons learned, in consideration of outputs and products developed by research, into concrete actions. A focused and extended engagement with stakeholders should be supported to address this concern. As such, future research approaches need include stakeholders from the beginning, to co-define research agendas and priorities to test for relative resilience to anticipated conditions. This engagement should be constant through key steps of the research, as it essentially enables policymakers to become co-owners of the findings. Stakeholder platforms, networks, and the AgMIP Impacts Explorer also provide additional opportunities to widely disseminate and advocate research findings so policymakers may consider them.

11.3 Zimbabwe

Currently, adaptation is driven by a national agenda and implemented by agricultural extension services and development agencies, with limited contributions by research and feedback from policymakers on decisions. Informed by the results from our baseline study (see also Section 5), multiple action areas were identified to enable research policy linkages in support of national goals and commitments. These include:

- The need for climate projections, impacts, vulnerabilities and adaptation strategies that are specific to local contexts, and useful to design national policy that supports adaptation actions that are tailored to local needs.
- The need for building human and institutional capacity to help plan and guide research and apply research finding to decisions, as well as feedback on applications by farmers for adjustments to adaptation interventions.
- The need for better institutional coordination, so that relevant data are collected, appropriately archived, and made available so they can be used to provide evidence for policy decisions and climate finance.
- The need for systematically involving experts, stakeholders and decision makers early in research planning, identifying research questions, design, implementation, interpretation of results and devising adequate dissemination channels, is critical to produce research that is useful and can inform policy, leveraging all the above.

The Way Forward

Experts from relevant disciplines expressed strong interest for the AgMIP A-Team Project approach to guiding adaptation scaling processes. The approach needs to be improved by identifying agricultural systems tolerance values, revision of layers and similarity thresholds that determine farm management decisions. The projections and adaptation recommendations also need to be tested within the different agricultural systems. We found this can be accomplished through virtual and face-to-face workshops in the following areas:

- Interactive revision and validation: Engaging with multi-disciplinary national and regional policy and decision makers and practitioners allows for reflection on co-developed scenarios and outcomes of integrated simulation modelling for guiding climate-change adaptation planning and action in the agricultural sector.
- Identifying drivers of change from policy to agricultural systems: Verification of drivers that influence the future of agriculture in Zimbabwe, adaptation strategies tailored to crop-livestock agricultural systems, and defining the role of research to make informed adaptation decisions.
- Building agriculture's future scenarios: Validation of future scenarios and understanding integrated assessment results, including the impacts of climate change, benefits to adaptation under different development pathways, scalability using the agro-ecological similarity approach and identification of entry points for research to support actionable policy-making effectively.
- Evidence for policy action: Revision of research results and jointly distilling key messages for policy and decision makers, to advance research-policy collaboration brings research information into a format that speaks to current changes in policy and is relevant to foster dialogue on implications for the countries vision 2030, NAPs, NDCs and SDGs
- Road maps for fostering research-policy collaboration: Synthesizing from our workshop deliberations and user stories from participants, the following actions enable the transformation of research-policy collaboration into action:

  - *Extend cross-scale dialogue* **-** Use virtual awareness creation workshops, including expert and user stories, to establish buy-in. Policy dialogue events that follow can showcase key results, and develop policy relevant key messages and briefs.
  - *Advance In-country capacity development* **-** National teams, experts, stakeholders and decision makers, need to trust, understand and apply the research methods and results, for comparative agricultural systems analyses to widen the evidence base for policy decision making and sustainable action, with methods evolving as policies change.
  - *Share evidence of impact for upscaling* **–** Provide feedback and strategic links to Government Ministries, including the sharing of results through their websites and information channels, to support continued progress. Act as a consortium to more effectively access funding mechanisms, e.g. Green Climate Fund, NAPs, NDCs.

11.4 Impacts Explorer

Online access to knowledge and information from trusted sources is of utmost importance for evidence informed adaptation planning. However, many tools, websites, databases and other online instruments are not easily accessible to non-English speaking audiences, which may contribute to existing knowledge gaps between stakeholders.

One of the advantages of online information sources is that information may be updated to include recent additions. In practice, funding is often aimed at developing online tools but not at maintaining the tool and its content. Information may quickly become outdated and lose its importance. The AgMIP IE is achieving a good level of maturity and reach to become a necessary platform for climate change adaptation in Low and Middle Income countries, however, it needs to be extended continuously and positioned with a strategic view, not just from the knowledge and research institutes developing it, but also from the funding organizations.

Funding of initiatives to improve accessibility and usability of existing tools (including adding translations), to continuously update the content, and to integrate tools and information sources where possible, have the potential to greatly increase the effectiveness of the current landscape of tools and instruments in this domain.

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13. Annexes

13.1 Table of Project Outputs

13.1.1 Ghana

Output Type	Title	Authors	Where it was published	Date of pub.
Book chapter	Potential Impacts of Agricultural Intensification and Climate Change on the Livelihoods of Farmers in Nioro, Senegal, West Africa.	MacCarthy D.S., Hathie I., Freduah B.S., Ly M., Adam M, Ly A., Nenkam A., Traore P.S., Valdivia R.O.	ICP Series on Climate Change Impacts, Adaptation, and Mitigation Vol. 5. Handbook of Climate Change and Agro-ecosystem: Climate Change and Farming System Planning in Africa and South Asia: AgMIP Stakeholder–driven Research, Part 2. Eds Rosenzweig, C.; Mutter C.Z.; Contreras E.M.1-29, https://doi.org/10.1142/9781786348791_0001	June 2021
Book chapter	Understanding Differences in Climate Sensitivity Simulations of APSIM and DSSAT Crop Models.	Boote K.J., Adam M., Ahmad I., Ahmad S, Cammarano D., Chattha A.A., Claessens L., Dimes J., Durand W., Freduah B.S., Gummadi S., Hargreaves J., Hoogenboom G., Homann-Kee Tui S., Jones J.W., Khaliq T., MacCarthy D.S., Masikati P., McDermid S., Murthy K.D., Nenkam A., Porter C., Ruane A.C., Subash N., Thorburn P., Traore P.S., Vellingiri G., Wajid S.A.	ICP Series on Climate Change Impacts, Adaptation, and Mitigation Vol. 5. Handbook of Climate Change and Agro-ecosystem: Climate Change and Farming System Planning in Africa and South Asia: AgMIP Stakeholder–driven Research, Part 2. Eds Rosenzweig, C.; Mutter C.Z.; Contreras E.M. 15-46, https://doi.org/10.1142/9781786348791_0002	June 2021

Output Type	Title	Authors	Where it was published	Date Pub.
Book chapter	AgMIP Regional Integrated Assessments: High-level Findings, Methods, Tools, and Studies (2012–2017).	Rosenzweig C., Mutter C.Z., Ruane A.C., Contreras E.M., Boote K.J., Valdivia R.O., Houtkamp_J., MacCarthy D.S., Claessens L., Adhikari R., Durand W., Homann-Kee Tui S., Ahmad A., Subash N. Vellingiri G., Nedumaran S.	ICP Series on Climate Change Impacts, Adaptation, and Mitigation Vol. 5. Handbook of Climate Change and Agro-ecosystem: Climate Change and Farming System Planning in Africa and South Asia: AgMIP Stakeholder–driven Research, Part 1. Eds Rosenzweig, C.; Mutter C.Z.; Contreras E.M. 123-142. https://doi.org/10.1142/9781786348791_0005	June 2021
Book chapter	Representative Agricultural Pathways: A Multi-Scale Foresight Process to Support Transformation and Resilience of Farming Systems.	Valdivia R.O., Homann-Kee Tui S., Antle J.M., Subash N., Singh H., Nedumaran S., Hathie I., Ashfaq M., Nasir J., Vellingiri G., Arunachalam L., Claessens L., MacCarthy D.S., Adiku S., Durand W., Dickson C., Mitter H., Schönhart M.	ICP Series on Climate Change Impacts, Adaptation, and Mitigation Vol. 5. Handbook of Climate Change and Agro-ecosystem: Climate Change and Farming System Planning in Africa and South Asia: AgMIP Stakeholder–driven Research, Part 2. Eds Rosenzweig, C.; Mutter C.Z.; Contreras E.M. 47-102, https://doi.org/10.1142/9781786348791_0003.	June 2021
Journal	Climate Change Impact and Variability on Cereal Productivity among Smallholder Farmers under Future Production Systems in West Africa.	MacCarthy D.S., Adam M., Freduah B.S., Fosu-Mensah B.Y., Ampim P.A.Y., Ly M., Traore P.S., Adiku S.G.K.	Sustainability, 13, 5191. https://doi.org/10.3390/su13095191	May, 2021

Output Type	Title	Authors	Where it was published	Date Pub.
Journal	AgMIP Regional Integrated Assessment of Agricultural Systems in Nioro, Senegal: Representative Agricultural Pathways, Climate, Crop and Economic Datasets	I. Hathie I., MacCarthy D.S., Freduah B.S., Ly M., Ly A., Porter C.H., Valdivia R.O., Ruane A.C., Antle J, Mutter C.Z., Hoogenboom G.	Open Data Journal for Agricultural Research, vol. 7, p. 27-38.	Oct, 2021 Accepted
Conference, oral presentation	Climate Change Impact on livelihoods of smallholders under current and future agricultural production systems in semi-arid Ghana	MacCarthy Dilys S., Clottey Joseph, Valdivia Roberto, Anaglo Jonathan N., Adiku Samuel G.K., Traore Sibiry P., Adam Myriam	2021 ASA, CSSA and SSSA Annual Meeting in Salt Lake City, UT.	07-11.11. 2021
Press Release	Stakeholders discuss new science-based tools for assessing climate change interventions and adaptation	MacCarthy D.S., and the Ghana A-Team	https://www.myjoyonline.com/stakeholders-discuss-new-science-based-tools-for-assessing-climate-change-interventions-and-adaptation/ https://www.graphic.com.gh/business/business-news/stakeholders-discuss-new-science-based-tools-for-assessing-climate-change-interventions-and-adaptation.html	April 2021
Policy Brief	Effective Climate Change Adaptation Planning in Ghana: The role of AgMIP for improved Climate Resilience	MacCarthy D.S., Valdivia R., Anaglo J., Madajewicz M., Clottey J., Adiku S., Amoah A.B., Amoako K.K., Quist E., Botchway V.A, Klutse N.A.B., Mutter C. & Rosenzweig C.	www.agmip.org	Dec 2021
Output Type	**Title**	**Authors**	**Where it was published**	**Date Pub.**

Info Brief	Climate Change Impact on Farmers' Livelihood; The Case for Navrongo, Ghana. Food Security in Ghana	MacCarthy D.S., Valdivia R., Anaglo J., Madajewicz M., Clottey J., Adiku S., Amoah A.B., Amoako K.K., Quist E., Botchway V.A, Klutse N.A.B., Mutter C. & Rosenzweig C.	www.agmip.org	Dec 2021

Engagement event with stakeholders (event name and description)	**Number of participants (% female)**	**Country where event took place (for virtual events, select the location of the main event organizer)**	**Date of engagement**
Review the draft RAPs narratives proposed by the Ghana A-Team three Shared Socio-Economic Pathways (SSPs). To develop DevRaps on the three SSPs with stakeholders and then harmonise it with the one developed by the Ghana A-Team.	13(31%)	Villa Cisneros Resort Ltd. Sogakope, Ghana	19th – 21st September, 2021
Building Agriculture's Future Scenarios: Climate Change Adaptation and Sustainability Pathways. AgMIP-CLARE Workshop.	14 (29%)	Villa Cisneros Resort Ltd. Sogakope, Ghana	30th March – 1st April 2021

13.1.2 Senegal

Output Type (Journal article, blog post, info-brief, etc.)	**Title**	**Authors**	**Where it was published**	**Date of publication**
Policy-Brief	Adaptation to climate change in Senegal: AgMIP's role of integrating regional research into National Adaptation Plans	Ahmadou Ly, Laure Tall, Diamilatou Kane, Ibrahima Hathie; Roberto Valdivia	IPAR website (www.ipar.sn)	November 1st 2021

Output Type	Title	Authors	Where it was published	Date Pub.
Info Brief	Influencing National Adaptation Plans by bridging the gap between research and policymakers	Ahmadou Ly, Laure Tall, Diamilatou Kane, Ibrahima Hathie; Roberto Valdivia	IPAR website (www.ipar.sn)	November 1st 2021
Journal Article	AgMIP Regional Integrated Assessment of Agricultural Systems in Nioro, Senegal: Representative Agricultural Pathways, Climate, Crop and Economic Datasets	I. Hathie, D.S. MacCarthy, B.S. Freduah2, M. Ly, A. Ly, C.H. Porter, R.O. Valdivia, A.C. Ruane, J. Antle, C.Z. Mutter, G. Hoogenboom	Open Data Journal for Agricultural Research	October 2021
Book Chapter	Potential Impacts of Agricultural Intensification and Climate Change on the Livelihoods of Farmers in Nioro, Senegal, West Africa. In Series on Climate Change Impacts, Adaptation, and Mitigation Handbook of Climate Change and Agroecosystems	Dilys S. MacCarthy, Ibrahima Hathie, Bright S. Freduah, Mouhamed Ly, Myriam Adam, Ahmadou Ly, Andree Nenkam, Pierre S. Traore, and Roberto O. Valdivia	World Scientific Publishing Company. World Scientific Publishing.	June 2021

Engagement event with stakeholders (event name and description)	Number of participants (% female)	Country where event took place (for virtual events, select the location of the main event organizer)	Date of engagement
Inception meeting with stakeholders (The objective was to present the CLARE project to key stakeholders)	16 (25%)	Senegal (IPAR office in Dakar)	March 9th, 2020
RAPs co-construction (build scenarios and identify key drivers of change)	11 (36.36%)	Senegal (Saly)	November 3rd-4th 2020
Building Agriculture's Future Scenarios: Climate Change Adaptation and Sustainability Pathways AgMIP-CLARE Workshop (Present AgMIP methodology and preliminary findings, engage a learning dialogue to understand better how to link science policy better)	22 (28%)	Senegal (Saly)	April 27th-29th 2021

13.1.3 Zimbabwe

Output Type (Journal article, blog post, info-brief, etc.)	Title	Authors	Where it was published	Date of publication
Journal article	Climate Change Impacts and Adaptation for Dryland Farming Systems in Zimbabwe: A Stakeholder-Driven Integrated Multi-Model Assessment	Homann-Kee Tui S., Descheemaeker K., Masikati P., Sisito, G., Valdivia, R., Crespo, O., Claessens L.	Climatic Change, doi:10.1007/s10584-021-03151-8	25.09.2021
Journal article	Enhancing benefits from climate change mitigation through adaptation efforts: crop livestock systems in semi-arid Zimbabwe	Homann-Kee Tui, S., Valdivia, R., Descheemaeker, K., Sisito, G., Moyo, E. N.	CABI A&B Special Collection on Agricultural Mitigation and Adaptation	2022 Writing in process
Book chapter Conference, oral presentation	Shaping National Decision Processes for Sustainable Climate Change Adaptation and Resilience building for Zimbabwe' Drylands	Homann-Kee Tui, S., Sisito, G., Moyo, E. , Dube, T., Valdivia, R., Madajewicz, M., Descheemaeker, K., Ruane, A	Springer Nature	Publication in process Presentation 21/7/2020
Book chapter	Transforming smallholder crop-livestock systems in the face of climate change: Stakeholder driven multi-model research in semi-arid Zimbabwe	Homann-Kee Tui, S., Masikati, P., Descheemaeker, K., Francis, B., Senda, T., Crespo, O., Moyo, E., Valdivia, R.	AgMIP Stakeholder-driven Research (In 2 Parts). Vol. 5, 217-276. World Scientific Publishing Company. World Scientific Publishing.	29.06.2021
Book chapter	Strengthening research-policy links for agri-food system transformation in Zimbabwe	Homann-Kee Tui, S., Hambloch, C., Valdivia, R	Les Dossiers d'Agropolis International https://www.agropolis.org/publications/agroecology.php	09.09.2021

Output Type (**Journal article, blog post, info-brief, etc.**)	**Title**	**Authors**	**Where it was published**	**Date of publication**
Conference, oral presentation	Scaling up sustainable intensification and adaptation to climate change in mixed crop livestock systems in Zimbabwe: a multi-scale co-design approach	Homann-Kee Tui, S., Valdivia, R., Descheemaeker, K., Sisito, G., Moyo, E. N.	Landscape 2021 conference, Diversity for Sustainable and Resilient Agriculture To be submitted for publication in special issue	21.09.2021
Conference, oral presentation	Transforming dryland farming under climate change: Benefits and trade-offs in mixed crop livestock systems in Zimbabwe	Homann-Kee Tui, S., Valdivia, R., Descheemaeker, K., Sisito, G., Moyo, E. N.	2021 ASA, CSSA and SSSA Annual Meeting in Salt Lake City, UT.	07-11.11. 2021
Blog	Simulation models alert on impact of climate change and need for smarter farming policies in Zimbabwe.	Homann-Kee Tui, S., Valdivia, R. Sisito, G., Dube, T. Bafana, B	https://www.icrisat.org/simulation-models-alert-on-impacts-of-climate-change-and-need-for-smarter-farming-policies-in-zimbabwe/ https://reliefweb.int/report/zimbabwe/simulation-models-alert-impacts-climate-change-and-need-smarter-farming-policies http://hub.ccouc.cuhk.edu.hk/news-and-info/simulation-models-alert-impacts-climate-change-and-need-smarter-farming-policies	28.05.2021

Output Type (Journal article, blog post, info-brief, etc.)	**Title**	**Authors**	**Where it was published**	**Date of publication**
Policy brief	Climate resilient agricultural systems in Zimbabwe: enhancing science - policy collaboration	Homann-Kee Tui, S., and the Zimbabwe A-Team	www.agmip.org	Dec 2021
Information brief	Climate change adaptation impacts in mixed crop livestock systems in southern Zimbabwe	Homann-Kee Tui, S., and the Zimbabwe A-Team	www.agmip.org	Dec 2021
CLARE Webinar	Need for smarter farming and food policies in Zimbabwe	S.Homann-Kee Tui, G. Sisito, T. Dube, E.N. Moyo, R. Valdivia, and AgMIP CLARE team		09.07.2021
IDRC learning review	AgMIP CLARE Learning Review	AgMIP CLARE team		25.03.2021

Engagement event with stakeholders (event name and description)	**Number of participants (% female)**	**Country where event took place (for virtual events, select the location of the main event organizer)**	**Date of engagement**
Revision of National Representative Agricultural Pathways: Climate change impacts and adaptation options for semi-arid Zimbabwe	9 (22%)	Zimbabwe	21-23.10. 2020
Agro-similarity Approach Zimbabwe, AgMIP CLARE Virtual expert consultation	15 (27%)	Zimbabwe, virtual, by ICRISAT	26.02.2021
Building Agriculture's Future Scenarios: Climate Change Adaptation and Sustainability AgMIP-CLARE Multi-stakeholder Workshop Zimbabwe	15 (27%)	Zimbabwe	14-16. 04 2021
AgMIP CLARE review workshop, Zimbabwe Building Agriculture's Future Scenarios: Climate Change Adaptation and Sustainability	8 (13%)	Zimbabwe	25-26.09. 2021

13.2 Info-briefs and Policy-briefs

A2.5.2 Ghana Testimonials

Environmental Protection Agency, (EPA)

Dr. Antwi-Boasiako Amoah: I am a Deputy Director at the Environmental Protection Agency, (EPA) Ghana, and I am in charge of Climate Vulnerabilities and Adaptation.

My exposure to the AgMIP RIA tool educated me on need to adopt such a forward-looking approach t to inform policy and investment decision on the appropriate adaptation strategies to promote, help in the identification of potential vulnerable groups under climate change, and provide evidence for prioritization and budgeting, with respect to policy formulation and implementation. Currently, the National Adaptation Plan (NAPs) process is at a stage where we need to assess the economic viability of the list of adaptation strategies available. I see this methodology to be very vital to this process. I will also recommend capacity building in RIA for other scientists and stakeholders beyond the project team to enable up-scaling the approach to include other farming systems in the country. An area I will like to see this methodology extended to is climate change mitigation, beyond adaptation. This is an area where information is grossly inadequate. The Environmental Protection Agency (EPA) would be willing to share results of this study and other materials such as the *Info* and *Policy* briefs on our web site as we participated in co-producing them.

Ministry of Food and Agriculture (MoFA)

Mr, Kingsley Kwako Amoako: I am a Deputy Director and Head of Environment and Climate Unit of the Ministry of Food and Agriculture, (MOFA).

We find the AgMIP (RIA) methodology useful to support our work in climate change impact and adaptation assessments within the agricultural sector in Ghana. Hence, we will like to see the methodology extended to other farming systems that contribute to the food basket in Ghana. We are willing to partner the AgMIP Ghana team in a future study and also request for capacity building in the use and interpretation of the outputs of the methodology. On priority research areas to contribute to the climate change adaptation discourse at the national level, more studies are required to assess the economic feasibility of Climate Smart technologies and practices. Additionally, studies on up-scaling and improving traditional farming practices, leveraging technology and new knowledge to support the climate change adaptation planning process, are required. We are interested in hosting the Impact Explorer on our website but we are currently technically challenged. Once we overcome the challenges, this will be done. . MoFA is interested in adding our logo on the Info and Policy briefs to which we have contributed as co-producers.

Animal Research Institute (ARS)

Mr. Vincent A. Botchway: I am a Senior Scientist at the Animal Research Institute, of the Council for Scientific and Industrial Research as well as the Secretary to the Climate Change Agriculture and Food Security (CCAFS)-Platform in Ghana.

I find the AgMIP methodology to be very interesting and very useful in contributing to the NAP processes since it generates data that is essential to support decision making process. I would like to see the methodology extended to other farming systems in areas such as the Coastal Savannah and Transitional zones of Ghana as well as crop-livestock integration. We (CCAFS) would like an improvement in terms of the ability of the methodology to factor in the multiple benefits derived from a crops as food and feed source to justify the potential use of the methodology in both the major and minor growing seasons. Upscaling the use of the method would require will require capacity building in the use of the tools for both scientists and policy makers. We therefore recommend capacity building for scientists and stakeholders beyond the AgMIP Team and we are willing to partner the AgMIP Ghana Team in a future study. A priority research area to contribute to the climate change adaptation discourse at the national level is "Assessment of agro-ecological based Climate Change Adaptation and Mitigation Potential of Crop-livestock Integrated farming systems".

A2.6 Senegal Policy- and Info-briefs and Testimonials

A2.7 Zimbabwe Infobriefs and Testimonials

2.71 Infobriefs

Climate resilient agricultural systems in Zimbabwe: enhancing science - policy collaboration

Key messages

1. Climate change is likely to adversely impact Zimbabwe's agricultural sector and its livelihoods. This can worsen poverty for wide parts of the population, already living under harsh conditions.
2. There is increasing awareness that research-based climate change adaptation should be central in agricultural systems transformation.
3. Government, development partners and private sector investments in agricultural programs started more diligently to incorporate climate change adaptation, building confidence and capacity to address climate change impacts.
4. However, there are gaps in linking local specific adaptation requirements to national level policy decisions: With data and evidence for context-specific effective responses, climate change and adaptation impacts can inform agricultural program design and match resources with activities.
5. Forward looking research that helps to understand farming systems specific vulnerabilities and adaption impacts, can be used to more effectively enhance policy coordination and mainstream climate change adaptation in agriculture.
6. Evidence-based assessments can contribute to support the rationale for climate financing and action.
7. Agricultural policy needs to be reviewed to enable the uptake of the research products and build human and institutional capacity in research, extension and climate services.

Introduction

Agricultural systems and livelihoods in Zimbabwe are being affected by multiple challenges, including climate change and other shocks such as COVID-19, in an unstable macro-economic environment, that will exacerbate poverty, food insecurity and malnutrition, in particular among small holder farmers.

Zimbabwe is projected to face drier conditions, with the South and West being more affected. There is strong model agreement on increasing temperatures, which will worsen the current dry conditions, e.g. causing soils to dry up quicker. Seasonal rainfall is expected to decrease, with late onset of the season, season shortening and higher frequency of extremes such as prolonged dry spells, droughts, floods, intense rainstorms. A higher prevalence of diseases, due to variations in climatic conditions, has potential to adversely affect crops and livestock. There is also evidence that semi-arid conditions are expanding in the country, which will increase the vulnerability to climate risk and food insecurity.

Despite the availability of the national climate policy, climate change response strategy, climate smart agriculture manual and framework, in-depth understanding of current and potential vulnerabilities and adaptation options at national and sub-national levels still remains limited. Agricultural, food security and climate policies and practices are often designed at national level, with limited vulnerability assessments that capture the specificity in local contexts and projections of future conditions.

Therefore forward looking research is required, which forms the basis of improved understanding and determination of climate risks and adaptation options for informed action. The generation of research results and products alone is however not enough. Currently, a lot of research is being conducted, with limited influence on policy making and action. This calls upon the need for policy review, to enable the uptake of the research products and strengthen relevant data collection. There is need to build human and institutional capacity to generate and make use of climate knowledge and inform associated extension and climate services, and feedback from applications by farmers.

About AgMIP CLARE

Responding to the need for more effort to enhance climate action, such as national and local-level planning processes and decision making in Zimbabwe, the AgMIP CLARE project aims to provide tools, data and information to better understand vulnerabilities of agriculture to climate change, and the performance of agriculture under plausible future pathways. The collaboration with a multi-scale and multidisciplinary range of experts and stakeholders in undertaking and validating forward-looking research is set to guide actionable agriculture and climate change policy decisions.

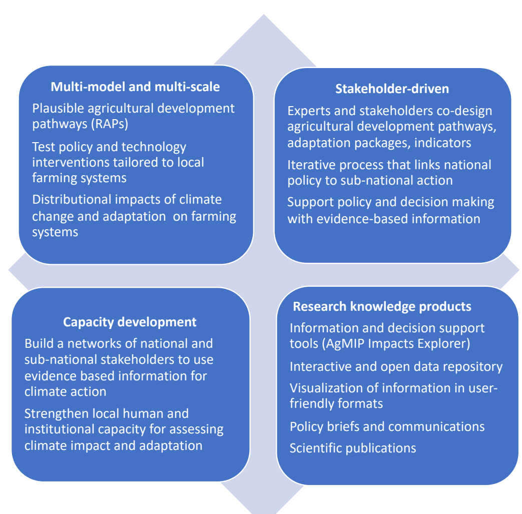


Figure 1. AgMIP research tools and data to support climate adaptation

Results from AgMIP CLARE

1. The need for research-based climate planning and action

Experts in Zimbabwe identified the integration of forward-looking research in policy processes as critical. This integration enables climate planning and action.

They identified multiple ways through which research can enhance climate change adaptation planning and action, in support of national and sub-national goals and processes.

Plausible agricultural development pathways: Improving forward looking research methods for analysing impacts of climate change and performance of specific agricultural systems under future conditions. This involves identifying key drivers of change to influence policy making, as conditions change.

Consistency in policy and decision making: There is need for increased efforts in widening the evidence base for adaptation in agricultural decision making. Such evidence could inform and subsequently improve policy coherence, better planning and coordination and ensure sustainability of actions.

Integrated agricultural initiatives: There is need to build a collaborative environment, taking advantage of agricultural research and development investments, such as LFSP, ZAGP, ZAKIS, ZRBF, to inform and increase adaptive capacity through policy processes. New initiatives such as forecast based financing, macro-insurance, should tap into research generated by AgMIP CLARE to guide impactful actions, and increase farmers resilience against possible climate and other shocks.

Strengthening national climate policy frameworks: Research projects, such as AgMIP CLARE, could thereby contribute to ongoing National Climate Policy (NCP), National Climate Change Response Strategy (NCCRS), CSA Framework, the GCF Country programme and the recently launched NAP Climate research programme, through anticipatory planning and action.

Synergies across sectors: The mismatch between sectors and policies is compounded by lack of collaboration between public and private sectors, in terms of the research that they are conducting.

There is need for collaborative research to develop and evaluate adaptation technologies.

Technical capacity: A program is needed on strengthening national forward looking research capacities, on new climate and integrated farming systems simulation methods, through more inclusive and equitable science partnerships, to effectively link science to decision making.

Research is therefore central for determining possible future pathways, and adapt to future conditions for agriculture. This also ensures progress towards meeting the national climate vision, strengthening Zimbabwe meeting its SDG commitments and goals of the Paris agreement.

2. Bridging research-policy gaps

For research to contribute to Zimbabwe's national climate change adaptation decision processes, with coherent approaches to sustainable agricultural development, the country can make use of its strengths and build on opportunities. Table 2 outlines the specific strengths, opportunities, weaknesses and constraints as they relate to research and development on climate change adaptation in agriculture.

Table. SWOC analyses by experts and stakeholders in Zimbabwe, related to

Strength - Foundation institutional structures exist that can be revitalized/strengthened to take up research, e.g. DRSS, ARC, RCZ, ZEPARU, universities - Existence of inclusive engagement platforms and processes, e.g. national climate change institutional framework, GCF country program - Existence of policy and legislative frameworks, e.g. RCZ, SIRDC - Education 5.0, promoting research-based innovation	Weakness - Limited interface to use research evidence in policy processes - Research messages not responsive to policy needs and not adequate to inform policy processes and implementation - Limited coordination and working in silos among government departments, development agencies and research - Capacity gaps in climate related research
Opportunities - Complex models that reflect processes and realities, scalable decision support - Political willingness and academically oriented ministers - Research to determine impacts of policies supporting investments, and visualize returns on those investments - New research approaches that can create better evidence base for funding adaptation action - National and international networks for research policy integration, e.g. AgMIP, RUFORUM	Constraints - Limited knowledge sharing platforms - Limited resources and competition - Limited monitoring and accountability systems - Inadequate human capacity and development thrust - Fragmented structures and processes - New threats like Covid-19

3. Going into action

Stakeholders provide guiding propositions for developing climate adaptation planning through science-based approaches, addressing the gaps identified.

1. Develop a priority research agenda for climate change adaptation planning, based on consultative cross sectoral processes, through higher level coordination mechanisms, such as RBZ
2. Improve access to climate and socio-economic data, such as climate and weather data, production, income, commodity, expenditure survey (PICES), made available as public good for assessments, to contribute to national processes, through the respective Ministries.
3. Establish and support platforms for interaction between policy makers, scientists and practitioners to share recent research findings, such as annual conferences and symposiums, through appropriate convening mechanisms
4. Capacitate and motivate researchers on writing policy relevant communications, such as policy briefs and communications. This includes public acknowledgements of research contributions.
5. Make policy relevant research information, success stories, available and accessible via platforms, networks, data bases and online media, through mandatory instruments
6. Key outputs from research projects that can influence policy making should be sustained, through deliberate efforts of involving key actors and orgnizations such as MSD, ZimVAC, UN Agencies; FbF CoP, NACOF/SARCOF.
7. Investments in climate research capacity to make use of and strengthen existing local level research programmes, eg. NAP training programmes at provincial staff and stakeholders. This should enable the collaboration with other institutions like MSD, ZINWA, and link those with national level research and development agencies.
8. Strengthen NAP process with evidence-based data and information on how policies, technologies and strategies may impact smallholder farmers. Engage stakeholders to demonstrate the tools and key results to support the NAP development process.
9. Mainstream research through research related budgetary allocations. These should upport collaborative climate relevant research proposal development to support Zimbabwe's commitments, e.g. the NAP and NDC processes, in response to identified gaps.

Conclusion

Climate change worsens poverty for wide parts of the population in Zimbabwe. There are multiple efforts to incorporate climate change adaptation in agricultural programs. However, there are gaps between research and policy that limit context-specific effective responses to climate change and adaptation. Resolving the disconnect between research processes and policy making through evidence-based decisions, will support the contribution of climate action to agricultural transformation. Forward looking research and improving researchers and stakeholders' capacity can be used more effectively to enhance policy coordination and mainstream climate change adaptation in agriculture. This process, of improving the research policy linkages and capacity development can contribute to support climate financing and action.

References:

von Braun, J., Afsana, K., Fresco, L.O., Hassan, M. (2021). Science for Transformation of Food Systems: Opportunities for the UN Food Systems Summit. Scientific Group for the United Nations Food Systems Summit 2021. https://sc-fss2021.org/

2.72 Testimonials

Infusing research in policy making through to implementation

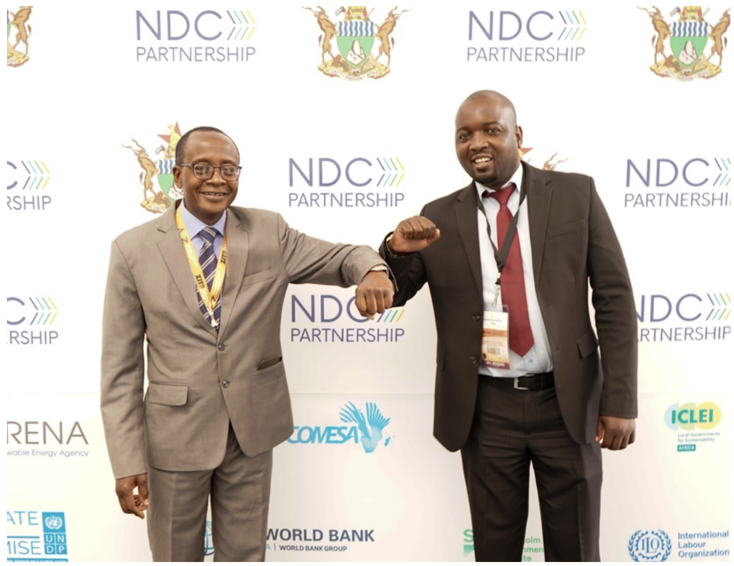
Washington Zhakata

Kudzai F. Ndidzano

Director and Deputy Director,

Climate Change Management Department,

Ministry of Environment, Climate, Tourism and Hospitality Industry



Important issue and why it is challenging or meaningful: AgMIP CLARE came in to address one of the main challenges to effective climate change adaptation in Zimbabwe. Development of climate change adaptation strategies has been restricted by limited availability of data and evidence to project future climate impacts under future conditions and inform required adaptation actions to adequately respond. The coming of AgMIP CLARE research closes some of the gaps relating to future climate scenarios and basis for undertaking local level specific climate change adaptation measures. Through strategic engagements, AgMIP CLARE research findings can be infused in the policy making processes through to implementation.

How AgMIP CLARE can support: The Government of Zimbabwe places high priority on the agriculture sector. The country steps up its climate actions in line with its own Vision 2030 and the Paris Agreement provisions, where both climate change adaptation (National Adaptation Plans, NAPs) and mitigation (Nationally Determined Contributions, NDCs) are critical to support the agricultural sector. Evidence and information generated from the AgMIP CLARE project can feed into the on-going NAP and NDC processes. As the implementation of the NDC and NAP is rolled out, the findings of AgMIP CLARE will become very useful and relevant in informing local level adaptation measures building on district level studies conducted by the project such as Nkayi.

User story: Through involvement with AgMIP CLARE, we had the opportunity to participate in the revision of future climate and adaptation scenarios for Zimbabwe as a country and implications for particular farming systems like mixed crop livestock farming in a District like Nkayi. This enhanced our understanding of the future climate impacts, as well as entry points for policy development and implementation, which are critical for strategic planning considering the expected future climate.

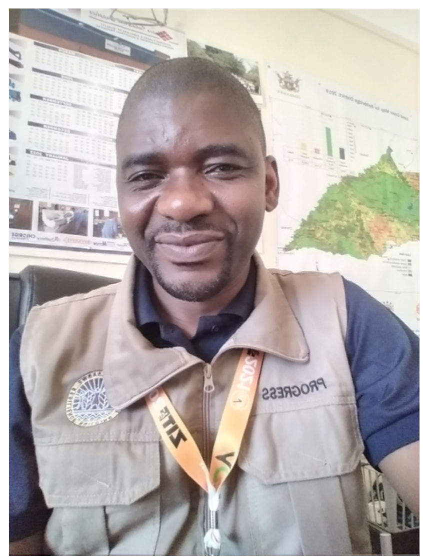
The AgMIP CLARE work complements the Climate Change Management Department's (CCMD) mandate on climate change assessments and planning for adaptation and mitigation actions with a focus on local level interventions supported by national policies. For long, reliance has been on international publications on future climate scenarios. Through AgMIP CLARE simulation modeling there is Zimbabwe specific high-resolution information available, which represents plausible future scenarios including details on climate and agricultural production. This closes some of the gaps witnessed in the past, and can help to build local experts' capacities in doing such research work. The outputs of the AgMIP CLARE are policy relevant and can be integrated in the National Adaptation Plan (NAP) and Nationally Determined Contribution (NDC) processes, which take the future climate and socio-economic scenarios as the basis for developing climate change adaptation for all sectors including agriculture.

In addition, the key messages as elaborated in the jointly revised Policy brief come in handy to reach out to policy makers, with evidence-based policy recommendations for strengthening research and policy linkages in the country. The recommendations inform effective and efficient climate change adaptation strategies towards resilient and sustainable agriculture in Zimbabwe.

The policy brief revision with the AgMIP CLARE team made us realize that a lot of relevant research is being conducted, however it is not fully feeding into the policy formulation processes. Various Government reports and plans including the National Communication and National Development Strategies, generate information and identify gaps that require research to develop scientific evidence to inform appropriate interventions. Importantly, there is need for early and continuous engagement of policy makers in identifying research priorities, sharing evidence through appropriate channels, e.g. tours, conferences and symposiums, which will be enhancing the collaboration between research institutions and Ministries, Departments and Development Agencies so that research findings are fed into the policy formulation processes. Furthermore, there is need to revitalize and capacitate existing research organizations, mobilize resources from national annual budgets as well as international organizations to sustain research addressing relevant climate change adaptation challenges. The CCMD structure has officers responsible for research coordination and stands ready for collaboration and facilitating demand driven research for development towards enhanced climate change adaptation and resilience.

The on-going NAP formulation and revised NDC prioritize climate smart agriculture as an adaptation measure with mitigation co-benefits. Going forward the CCMD will integrate the findings of the AgMIP CLARE into the formulation of the NAP which is to be finalized in 2022 and the NDC implementation action plan. These will include the results of future climate scenario modelling to inform adaptation options that have been contextualized for specific agricultural systems and agro-ecological zones. Further, CCMD will also integrate proven adaptation measures from the studies as pilots in the on-going and planned demonstrations of climate change adaptation measures. The findings of the project will also be used to inform the climate change adaptation project formulation as the country will be pursuing various climate finance facilities such as the Green Climate Fund and Adaptation Fund where CCMD is the Focal Point. The simulation models projecting performance of particular interventions will thereby build on what is already there, high level NDC options, and help to define adaptation and mitigation interventions that are meaningful for particular contexts and clients.

Linking farming communities and extension services with research on climate resilient agriculture



Gevious Sisito

Principal Research Officer

Matopos Research Institute

Important issue and why it is challenging or meaningful: With Zimbabwe enhancing its diligence in climate resilient agriculture, National research institutions were selected as entry point for GCF. Their role is in packaging technologies and interventions for extension services, who have the direct links with farmers and reach wide parts of the population, as more than 90% of population is involved in agriculture. This provides opportunities for training and demonstrations of adaptation technologies and interventions, and improving access to weather, climate and hydrological information.

How AgMIP CLARE can support: Matopos Research Institute hosts one of the GCF-funded Innovation Platforms (IPs), for testing climate change adaptation packages under semi-arid farming conditions. This contributes to climate proofing technologies and interventions for specific farming systems, under current climatic conditions and projected climate impacts. AgMIP integrated assessments can provide information about benefits and impacts of specific technology packages, and to what extend agricultural extension services needs to be improved, and thereby becoming more relevant for farmers.

User story

There is a growing demand for AgMIP CLARE integrated assessments and collaborative research tools. The AgMIP CLARE tools are handy to make research more useful. They can test the impacts of particular adaptation packages that have been proven to work, under particular farming systems and climatic conditions. This can support mainstreaming climate change adaptation in agriculture, through better tailored technology packages, and requirements for these packages to work.

At the same time, this type of research offers opportunities for building capacity. Capacity gaps exist how to carry out climate related research with specific focus on agriculture. Currently, adaptation packages are being promoted, which have not been tested using the right tools. Using AgMIP CLARE tools, integrated assessments can be done through DRSS, to develop sets of adaptation packages and information that the IPs can use.

Through the IP we congregate relevant stakeholders to take the research results further, involving researchers, farmers, private sector, government and development organizations. We create a common understanding on the challenges for agriculture under climate change, what technologies work under climate change, to what extend they can contribute to increase farm productivity and farm income, and enhance the contribution of agriculture to GDP growth, as it is the backbone of Zimbabwe’s economy.

The IPs thus develop new ways of grounding agricultural research in application and extension; making AgMIP CLARE foreword-looking tools available to the IPs helps fostering these bonds.

AgMIP CLARE research methods can thereby strengthen the role of IPs to become applied oriented learning centers, and build capacity of extension services on climate resilient agriculture. They can help to bridge research with agricultural extension services and rural communities.

Academia building capacity for strengthening climate change adaptation in Zimbabwe

Thulani Dube

Social Scientist

Lupane State University

Important issue and why it is challenging or meaningful: During AgMIP CLARE work the opportunity was identified to enhance the universities capacity on forward looking research approaches. This would contribute to strengthen academic linkages to decision makers in strategic implementing organizations, such as development agencies and government departments (e.g. Meteorological Services Departments, Agricultural and rural development). This can help to infusing research-informed decisions through a wider network of actors into national policy decisions, supporting climate change adaptation.

How AgMIP CLARE can support: Lupane State university, has established a new MSC program on climate change and sustainable development. The University introduced the AgMIP CLARE Regional Integrated Assessment approach as component in its MSc curriculum. AgMIP CLARE through capacity development on simulation modeling, running through the MSc program, can support a better understanding of vulnerability to climate change and adaptation strategies effectively contributing to sustainable agriculture.

User story

Through participation in AgMIP CLARE, the greatest opportunity for me was the awakening of potential of forward-looking approaches in terms of climate simulations and integrated modeling.

The approaches at our university had been mostly backward looking, in terms of assessing evidence of climate change impacts, and reacting to impacts based on historical evidence. We have now introduced a new section in one of the modules titled 'Key Concepts in Climate Change and Sustainable Development'. We are looking for possibilities of utilizing the forward-looking approaches from AgMIP CLARE in our portfolio. This will help us to capacitate students that enroll with us. Some of these students represent critical positions in organizations dealing with climate change adaptation strategies.

The stumbling block for us to implement the assessments is capacitation of university staff on the framework and modeling tools. We think that capacitation would be helpful for us to be able to deliver the methods effectively.

The critical issue is that we have important stakeholders attending our MSc program, including staff from international NGOs, local CBOs and government departments. We think that capacitating them with the AgMIP CLARE approaches could be a good platform to infuse and create multiplier effects.

Other universities are running the same MSc program on climate change and sustainable development e.g. Bindura University of Science Education, as part of a SADC imitative. These are further opportunities to extend the partnership and use of forward-looking research approaches.

Furthermore, the Department of Climate Change Management chose one university in each Province of Zimbabwe, to train provincial and district staff members, administrators and stakeholders to mainstream climate change adaptation into their development plans, as part of devolution strategies. Lupane State University is part of that process. As a knowledge generator and disseminator, we provide resource people to train the district's technical staff.

Capacitating universities with the AgMIP CLARE forward-looking research methods is thus a strategic move.

To initiate the capacity development, and broadening the audience, while minimizing costs, a first step could be to organize a symposium. From there we would move on with interested researchers and post graduates, to apply the methods in their research. This could enhance the transfer of knowledge from the AgMIP CLARE project to experts and decision makers to be targeted in the various regions and farming systems of Zimbabwe. It would raise awareness and promote research-based results to develop more local specific climate change adaptation strategies.

AgMIP tools aid climate model selection, projections data access and analysis in Zimbabwe

Dr Elisha N Moyo, Climate Scientist
Climate Change Management Department,
Ministry of Environment, Climate, Tourism and Hospitality Industry

Important issue and why it is challenging or meaningful: As the climate change challenge takes its toll on Southern Africa's livelihoods, food security, lives, property, energy access, agriculture, Disaster Risk Management, Zimbabwe is not been spared. The climate change problem as a fairly new phenomenon. Critical challenges for developing countries such as Zimbabwe are skills and capacity to determine and understand the vulnerability of different social and economic sectors. Zimbabwe lacks the necessary capacity in climate data analysis, technical skills, equipment and related paraphernalia to objectively select appropriate climate models which assist in accurately answering pertinent questions such as the "adapt to what" - what is the magnitude and direction of change expected, where and when. Past adaptation efforts, policies, strategies and practice have largely been informed by the then available model data without adequate interrogation of the models themselves due to general unavailability. This, researchers argue, could lead to mal-adaptation and inconsistencies.

Climate models as some of the latest tools that provide some means of determining or understanding what the future who likely be in view of climate change are therefore crucial. The increasing number of models has however also brought challenges as there are conflicting model results which confuse the practitioners and policymakers in terms of what they should be preparing for or answering the 'adapt to what' question.

Furthermore, capacity to access and let alone downscale or analyse climate models in most of our government institutions within Zimbabwe and most developing African countries is limited. Resultantly, most national and key strategic climate analyses and projects have been reliant on one or two universities outside Zimbabwe to access climate model data, especially future climate projections. Due to the complexity of the climate modelling discipline itself, many researchers within the country were finding it difficult to access and analyse climate data.

How AgMIP CLARE can support: AgMIP provides easy to use simple tools in data which include climate future climate projections for almost all the models available in the earth system grid. Furthermore AgMIP provides the required tools such as R-programming scripts which can be adapted to any part of the world by simply inputting the coordinates of the area under review. This enables scientists, even those without much detailed knowledge about programming to be able to access and analyse future climates scenarios and climate projections.

User story: In my work within the Department of Climate Change Management and as a scientist (climate dynamics, climate services, climate modeling and applications in early warning, climate risk management and agriculture) interested in understanding the rainfall dynamics in Zimbabwe and southern Africa, I found the AgMIP tools and data being user friendly. I used the AgMIP T & P GCM Model section approach in my doctorate research, which sought to understand and investigate the historical and future climate dynamics in Zimbabwe, to select representative models for use analysis of climate projections and investigation of the impact of climate change on maize production.

This methodology enables classification of climate models as hot/cold or dry/wet to enable better appreciation of possible skewness of the model results. This is transformative in that it gives scientists, policymaker's and practitioners an understanding of the likely climate direction or the convergence or divergence of models when it comes to the future scenarios. It also enables researchers to understand the certainties around climate modelling or the confidence in the projections which could be carried to the impact studies. I also applied the knowledge gained from AgMIP in contributing towards reviewing the climate model results of the National Water Resource Master Plan development.

In providing the methodologies, tools and data, AgMIP dealt with challenges that come with the monopoly associated with climate modelling development within the sub region as previously, few scientists were able to venture into climate modelling space. I therefore recommend that AgMIP methodologies, tools and data be made more available to universities, researchers, young scientists and technical departments in government so that more work is done to better understand the climate of Zimbabwe in southern Africa. This will not only contribute to the board of knowledge on rainfall and climate change or climate dynamics but aid climate action, decision-making and policy-making which will ultimately enhance food security, livelihoods, DRR and climate risk management.

Communicating research evidence and informed policy decision for climate change adaptation

Busani Bafana
Journalist and
Communication Specialist
Bulawayo, Zimbabwe

Important issue and why it is challenging or meaningful: The benefits of science research and effective policies are not widely understood because they are not well communicated.

Science research and policy advocacy are technical and complex but relevant and beneficial for development. As a journalist, I realise the importance of effective communication of research outputs and more importantly, in a manner that enhances understanding and cements the relevance of science research in informing policy and decision making. If science research messages are well communicated, policy makers are better engaged and spurred to action effective policies to support agriculture development, specifically how Zimbabwe responds the impacts of climate change.

How AgMIP CLARE can support: The AgMIP RIA tool gives future insights on the state of farming systems on the back of changing climate providing a trigger for informed remedial action. The tool builds scenarios (changes in temperature and precipitation, crop production, soil fertility, crop and livestock management) to show farming systems in the present and the future through the assessment of climate change impacts.

Collaborative research fosters evidence-based polices responsive to the needs of farmers. This ensures that there is no reliance on 'common knowledge' in policy development and implementation. The AgMip methodology is diagnostic, making it strategic in development planning. By modelling what is unknown and unseen into possible scenarios is helpful in preparing the agriculture sector to response to both the positive and negative impacts of a changing climate. I see the role of science communication in unpacking and documenting the AgMip outputs through science news articles, features articles, blogs and interactive infographics to aid understanding about the tool and how it can complement national adaptation initiatives and support climate change policy implementation.

User story: During the engagement process to promote and understand the tool, a most important lesson for me was the impact of simple communication in targeting policy makers. The need for research outputs to be effectively communicated starts with multi-stakeholder consultations. By bringing together a multiplicity of actors (farmers, policy makers, government, private sector, non-state actors, researchers) the tool enables the development of informed, robust policies for the benefit of the agriculture sector.

Research processes must be collaborative and participatory. Researchers are knowledgeable in their area of expertise but there is a gap in the public access to their research outputs. Research, including the development them better articulating their findings to the 'common man'. A barrier is the disintegrated approach to disseminating research evidence and engaging policy makers and advocates.

Furthermore, research outputs must be communicated in lay man's terms. It is said if you can tell your grandmother what climate change means then you have made your message clear. Speak the common language. There is scope to capacitate the media on research and policy collaboration so that they can tell the story. Technical issues need to be broken down into simple knowledge products that will aid public understanding and awareness on research outputs.

Media engagement through facilitated training is one idea. Science research is important for the development of society and economic growth. It is fundamental in the development of health, environmental protection and agriculture.
Researchers are convinced the outputs of their work contribute to a better society and therefore it is critical that these outputs are well communicated to the public and more strategically in informing policy development.

I could not have been more prepared to apply the principle of effective communication when I participated in the revision of a policy brief assessing and highlighting the AgMIP tools. I realised the strength of identifying messages in knowledge products for public information and in this case policy advocacy. Policy makers are important actors in the development narrative. Messages aimed at them with the intension of getting them to take policy action on particular issues need to be clear, simple and yet detailed to trigger the desired policy action. We revised the policy brief paying attention to using simple and concise language that speaks to policy makers. This meant eliminating where possible technical scientific terms and were these are used, explaining them for understanding.

This will enable the AgMIP project to better engage stakeholder and communicate more effectively. Roundtable dialogues between media researchers and policy makers would help in issue engagement and effectively communicating research outputs and policies in this case dealing with climate change adaptation. Organising policy dialogues bringing together the multiplicity of actors, farmers, researchers, policy makers, advocates will help towards informed policy making and appreciation of science research outputs.

Building capacity of all stakeholders in promoting the AgMIP project is an important consideration. Researchers can help build the capacity of policy makers and in my case, of the media in understanding the AgMIP tool. There is a gap in the media understanding of research outputs and how policies work. Promoting research/policy collaboration should also entail training the media on the workings of researchers and how policies are developed and adopted. This will help in them articulate the issues succinctly,

The AgMIP tool has offered important insights on future climate scenarios. How do we prepare for the envisioned changes through revising or developing appropriate adaptation policies? For me I believe the next steps from this will include going to the ground to assess how are farmers adapting the current climate change impacts, are our current policy frameworks helping farmers adapt? In addition, I would want to document the engagement processes with farmers/policy makers in the context of the promotion of the AgMIP Tool in which modelling has been done.

I would also want to document how current policies are supportive adaptation approaches in Zimbabwe and how the AgMIP tool is providing insights that will inform policy and decision making. This means making a physical trip to Nkayi which is a representative sample site of the study the AgMIP tool has been tested.

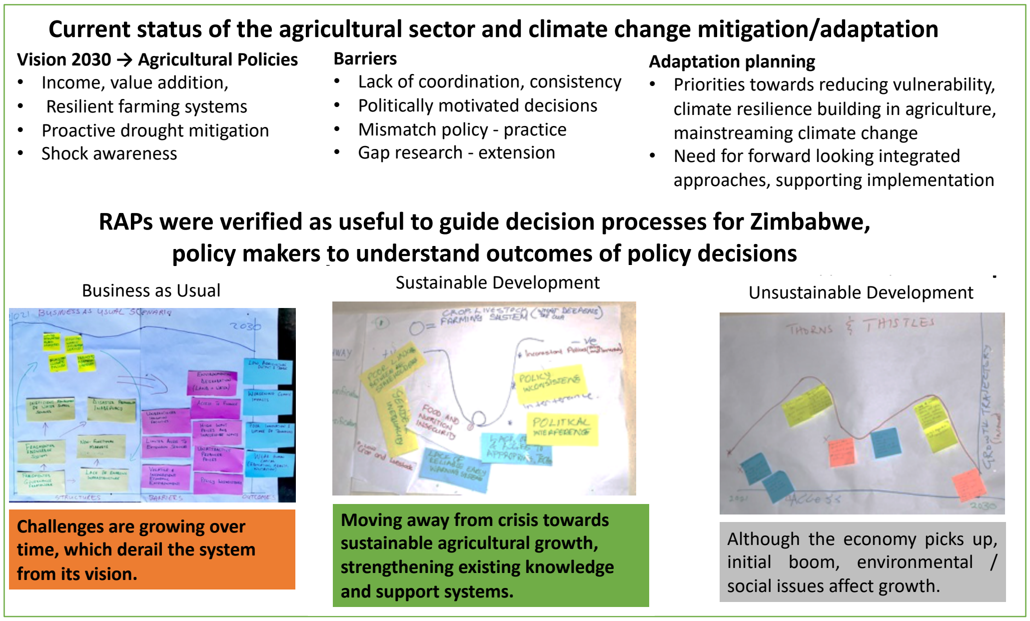
The research outputs need to be widely promoted and I see my role in adding this dissemination through write articles that are published on various platforms, including the Ministry website showing how research/policy collaboration will advance research informed policy decisions.

Social media outreach can facilitate further dissemination of research outputs. This will benefit the AgMIP project in sharing information widely to create awareness. More importantly agriculture being a pivotal sector in Zimbabwe's economy, there is greater need to promote the adoption of proven technologies by farmers to better their production while at the same time raising incomes and improving livelihoods. On the back of government's grand scale promotion of the Intwasa/Pfumvudza approach which in 2020/2021 season has been attributed to the national bumper crop harvest in maize and small grains.

A2.8 Draft Protocols: Integrated National and Regional Assessments

Annex 3. Supplementary Technical Information, Figures, Flow-charts, etc.

A3.1 A-Team Technical Matter



Engagement of stakeholders to identify in pathway development benefited from hands-on approaches

A3.2 Baseline Technical Matter, Questionaires, Interview Guides

Additional information about interviews

The categories of interview questions were:

- The main vulnerabilities and adaptations in the agricultural sector on which the respondent's work is focusing
- Successes in national climate change planning for agriculture
- Obstacles to national climate change planning and adaptation in agriculture
- Sources of influence in the national planning processes
- Information that respondents have been using in their work related to climate change in agriculture
- Obstacles to use of existing information
- Information needs
- Needs for new research
- Impacts of the pandemic on the respondents' work and on national planning processes

We conducted the interviews by telephone. The team translated the interview guide for Senegal into French.

Additional information about surveys

We programmed the survey questionnaires in Survey Monkey. The respondents received a link to the survey. They filled it out on their own computers. We translated the questionnaire for Senegal into French.

Seventy-six percent of survey respondents say that they are or have been involved in climate change and/or adaptation planning processes for agriculture in their countries. The percentage varies from 63% in Ghana, to 78% in Senegal, to 88% in Zimbabwe. A third to a half of the survey respondents represent government organizations, depending on the country. The second most common institutions are national academia, followed by national research organizations, international development and technical assistance organizations, civil society organizations and national NGOs, international NGOs, and very few individuals from the private sector. The majority of respondents are at the senior levels of their organizations, with somewhat greater representation of middle and junior levels in Zimbabwe. Respondents fulfill a range of responsibilities, with the most frequently mentioned roles being program implementation, capacity building, coordination, and planning. They represent a range of areas of expertise, with the most frequently listed areas being vulnerability and adaptation to climate change, project management, and environmental management.

A3.3 RAPs Technical Matter

- 3 national RAPs
- 3 regional RAPs
- 1 policy matrix

A3.4 Webinars and Workshops Technical Matter

A3.5 Agroclimatic Similarity Methods

Table A3.1: Layers factored into agroclimatic similarity analysis for Nkayi, Zimbabwe.

	Variable Layer Name	Units	Product Spatial Resolution	Product Temporal Resolution	Evaluation Period	Nkayi farms avg value	Similarity Range	Product Description
Biophysical Layers	**Mean NDVI***	NA	250 m	16-Day	2000-2020	--	--	MOD13Q1
	Min NDVI*	NA	250 m	16-Day	2019- 2020	--	--	MOD13Q1
	Max NDVI*	NA	250 m	16-Day	2019- 2020	--	--	MOD13Q1
	Mean EVI	NA	1km	16-Day	2000-2020	0.2661	0.2394 to 0.2927	MOD13A2
	Min EVI	NA	1km	16-Day	2000-2020	0.0935	0.0692 to 0.0622	MOD13A2
	Max EVI	NA	1km	16-Day	2000-2020	0.6252	0.5462 to 0.6008	MOD13A2
	DOY min EVI*	Julian Day	1km	16-Day	2000-2020	--		MOD13A2
	DOY max EVI*	Julian Day	1km	16-Day	2000-2020	70	65-75	MOD13A2
La	**Land Cover***	Classes	1km	10-year	2010-2019	--	--	MODIS

	Soil Moisture Profile	Root-zone fraction	10 Km	3-Day composites	2016-2020	0.25	0.225 to 0.275	NASA enhanced SMAP
	Subsurface Soil Moisture	mm	10 Km	3-Day composites	2016-2020	25.87	23.283 to 28.457	NASA enhanced SMAP
	Agro-Ecological Zone (AEZ)	NA	NA	1-year	2020	III & IV	III & IV	Zimbabwe National Geospatial and Space Agency
Current Climate Layers **	**# Extreme Heat Days (Tmax > 35 ℃)**	Days	0.5˚	Daily	1990-2020	5	4 to 6	ISIMIP3 Ensemble of 5 Bias-adjusted General Circulation Models (GCMs; Lange et al., 2019)
	Total Precipitation	mm	0.5˚	Daily	1990-2020	636	572 to 700	ISIMIP3 Ensemble of 5 Bias-adjusted GCMs
	Mean Temperature	℃	0.5˚	Daily	1990-2020	23.2	20 to 25	ISIMIP3 Ensemble of 5 Bias-adjusted GCMs
	# Rainy Days (P > 1 mm)	Days	0.5˚	Daily	1990-2020	59	52 to 65	ISIMIP3 Ensemble of 5 Bias-adjusted GCMs
Future Climate Layers **	**# Extreme Heat Days (Tmax > 35 ℃)**	Days	0.5˚	Daily	2040-2070 (SSP585)	30.5714	27 to 34	ISIMIP3 Ensemble of 5 Bias-adjusted GCMs
	Total Precipitation	mm	0.5˚	Daily	2040-2070 (SSP585)	672.8741	605 to 740	ISIMIP3 Ensemble of 5 Bias-adjusted GCMs
	Mean Temperature	℃	0.5˚	Daily	2040-2070 (SSP585)	25.57	23 to 28	ISIMIP3 Ensemble of 5 Bias-adjusted GCMs
	# Rainy Days (P > 1 mm)	Days	0.5˚	Daily	2040-2070 (SSP585)	57.92	52 to 64	ISIMIP3 Ensemble of 5 Bias-adjusted GCMs
Future Climate Change Layers **	**Change in # Extreme Heat Days (Tmax > 35 ℃)**	Days	0.5˚	30-year means	SSP585 2040-2070 vs. 1990-2020	25.5	23 to 28	ISIMIP3 Ensemble of 5 Bias-adjusted GCMs
	Change in Total Precipitation	% of baseline	0.5˚	30-year means	SSP585 2040-2070 vs. 1990-2020	-0.6783	-0.61 to -0.75	ISIMIP3 Ensemble of 5 Bias-adjusted GCMs
	Change in Mean Temperature	℃	0.5˚	30-year means	SSP585 2040-2070 vs. 1990-2020	2.38	2.28 to 2.45	ISIMIP3 Ensemble of 5 Bias-adjusted GCMs
	Change in # Rainy Days (P > 1 mm)	Days	0.5˚	30-year means	SSP585 2040-2070 vs. 1990-2020	-1.215	-1.0 to -1.33	ISIMIP3 Ensemble of 5 Bias-adjusted GCMs
Socioeconomic Layers	**Population Density**	persons / km	1 Km	5-year	2000	20.98	18 to 22	GPWv411 Population Density
	Population Density	persons / km	1 Km	5-year	2020	26.146	23.5 to 28.75	GPWv411 Population Density
	Livestock Density- Cattle	# cattle / pixel	0.83˚	1-year	2010	1527.128	1374 to 1680	Gridded Livestock of the World
	Livelihoods	NA	NA	1-year	2020	ZW09	ZW09, 16, 17, 21, 24	Zimbabwe National Geospatial and Space Agency (ZINGSA), 2020

* Layer not a focus of current analyses

** Calculated over the Maize growing season for each ½ degree pixel (Müller et al., 2017)

A3.6 National Gridded Crop Modeling Technical Matter

A3.7 National Economics Technical Matter

A3.8 Toward Integrated National and Regional Protocols Technical Matter

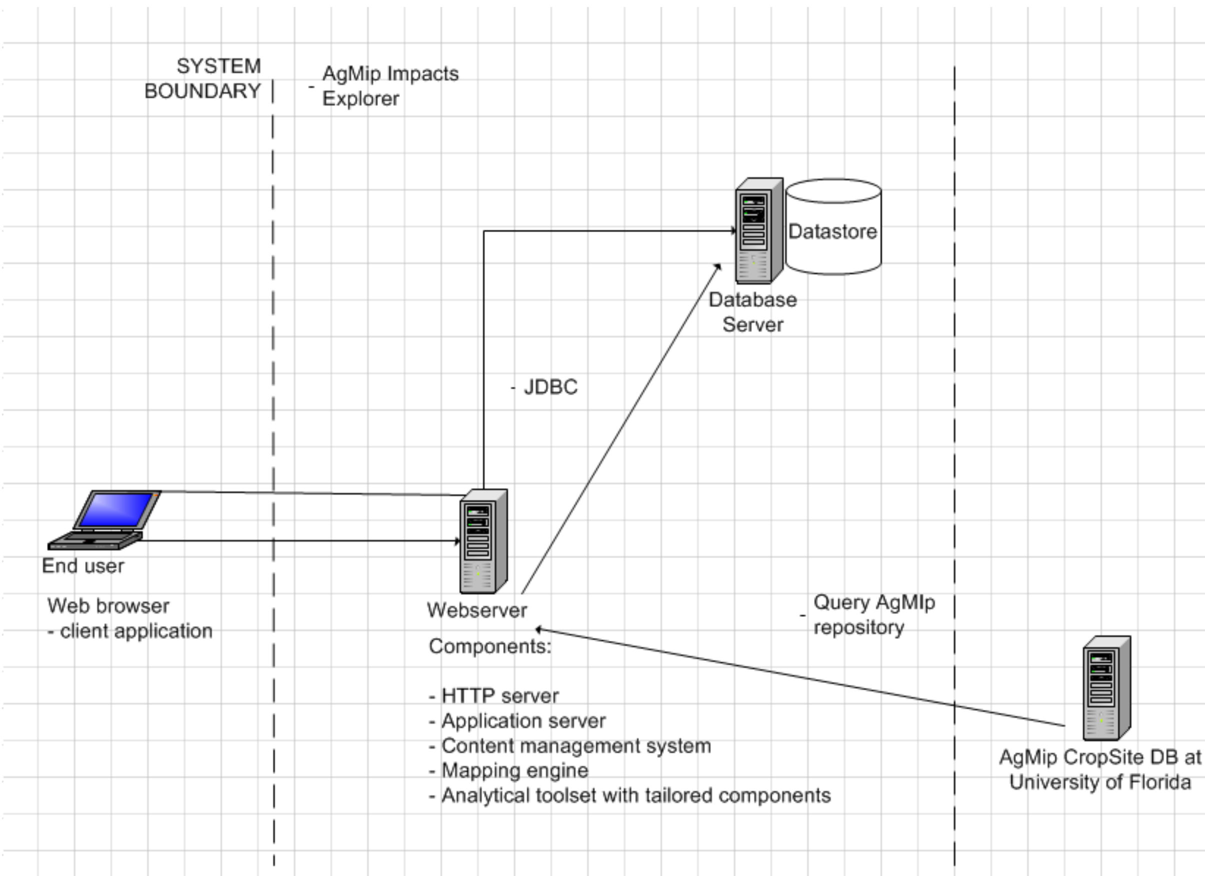
A3.9 Technical characteristics of the AgMIP Impacts Explorer website

This chapter describes the technical characteristics of the AgMip Impacts Explorer website. The leading principle behind the choices was to opt for open-source components. Open source products are mature and widely used. They have many advantages: no license costs, vendor independent, hosting can easily be transferred.

Technical architecture

The technical architecture of the Impacts Explorer website is presented in the scheme below.

Components of the technical architecture of the Impacts Explorer.



The Database Server runs on a shared environment at Wageningen Environmental Research. Shared means that these servers are shared with other websites. The database is duplicated: we have a test and a production database.

The components of the Application Server run on the Kubernetes cloud environment of WUR. All components have test and production implementation, so new versions can be prepared and tested independent from the production environment.

Description of technical components

Users access the AgMip Impacts Explorer by their web browsers. The current versions of all major browsers are supported. The website output to the clients consists of a combination of HTML and Javascript. HTML for textual information and images, Javascript for dynamic interaction at the client. The Javascript components inside the spatial dashboard and the data exploration tool are based on the ExtJS software library. The map interface from the spatial dashboard relies on Google Maps.

The webserver contains the following components:

- HTTP server
- Application server
- Content management system
- Mapping engine
- Analytical toolset with tailored components

The HTTP server used in the cloud environment is NgInx. Nginx does simple tasks like serving files. More complex tasks are handled by an application server. This is an engine that allows handing over requests to pieces of software that are tailored for their tasks. On this topic the Impacts Explorer relies on Apache Tomcat. Apache Tomcat enables to execute software components that are written in Java. Java is platform independent, and widely used. And there are many good open-source products available which are developed in Java and which can be used within Apache Tomcat.

The first one is the Liferay Content Management System, which simplifies and supports to enter and maintain the content of the AgMip Impacts Explorer website. Liferay provides the core functionality for this task. As Liferay is written in Java it can be extended and integrated with own tailor made components, but so far there was no need to do so.

Another Java based products that can run within Apache Tomcat is the Geoserver mapping engine. Geoserver supports on-the-fly geospatial functionality like map creation based on the standards of the Open Geospatial Consortium (OGC). The maps that are created from AgMip rely on Geoserver for this task.

Finally there is a set of tools and components that has been developed to access and handle the AgMip project data as they have been produced by the teams with the help the technical leaders. These components have been written in Java. There are several parts:

- Query the AgMip cropsite database which is hosted by the University of Florida;
- Handle data updates and store them in the database;
- Data preprocessing;
- Handle client side requests to deliver the pieces needed to the client application.

The database server stores the data in relational database. For the Impacts Explorer PostgreSQL is used. Geospatial functionality is provided by PostGIS, an extension of PostgreSQL.

Details of the used open source software products

All used components are open source products which run under Linux and under Windows. The details of the version used are:

- HTTP server: Nginx, latest version (automatically handled by cloud deploy);
- Application server: Apache Tomcat 8.5 (automatically handled by cloud deploy);
- Database: PostgreSQL 12, with the PostGIS2.0 geospatial extension;
- Content management system: Liferay 7.4;
- Mapping engine: Geoserver 2.18.2
- Javascript library: ExtJS 7.3.1

Food Security in Ghana

October, 2021

The Agricultural Model Intercomparison and Improvement Project

Climate Change Impact on Farmers' Livelihood; The Case for Navrongo, Ghana.

Photo Credit: Samuel Adiku

Key Messages

Projected changes in agricultural production systems, in response to developmental goals as well as commodity prices, if adopted will lessen the negative impact of climate change on farmers' livelihoods under future production system even though a significant proportion of farmers will remain vulnerable.

Using heat tolerant crop varieties has the potential to further reduce the proportion of farmers vulnerable to climate change.

Climate

- **Temperature increases are projected for Navrongo**. High and moderate emission scenarios would result in up to 1.9 and 2.7 °C respectively by the 2050s
- **Changes in rainfall are projected to be variable:** An increase of up to 10% in total amounts is expected while the number of rainy days would reduce by 13%.

Vulnerability

- **Peanut,** as it is cultivated today, is not vulnerable to climate change and would almost always benefit from it. **Maize** is highly vulnerable, while **Sorghum** is moderately vulnerable to climate change and could either slightly benefit or suffer from it.
- **In tomorrow's production system**, **maize** continues to suffer from climate change, while **sorghum** remains relatively unaffected and could slightly benefit or suffer from it. **Peanut** still almost always benefits from climate change.

Adaptation

- A long crop life cycle is sufficient to reduced the negative impacts of climate change on the cereals, especially maize, while peanut only benefits marginally

Vulnerability to climate change under current and future production systems in Navrongo, Ghana

Current Production System

Continuation of the current agricultural system under future climate conditions (2050) would lead to reductions in maize yield by 12 to 20%. On the other hand, sorghum yields would largely be unaffected by climate change, apparently due to its relatively higher tolerance to higher temperatures and drought stress. Peanut, unlike the cereals, will benefit from climate change due to projected CO_2 fertilization. The practice of the current agricultural production system under future climate conditions would result in between 48 to 59% of households becoming vulnerable to climate change. This translates into a reduction in net farm returns and up to 7% increase in poverty.

Future Production System

In the future, agricultural production systems at Navrongo are expected to use improved seeds, planting density, and fertilizer applications. Further, it is also expected that advancements in socio-economic, institutional, biophysical and technological systems would improve overall productivity. For this future production system, two scenarios of productions were assessed; sustainable, and fossil fueled, development pathways. Under these future systems, climate change impact on maize would still be negative compared to sorghum. In both cases, however, the impacts would be more severe in the future production systems compared with current production system. Peanut would continue to be positively impacted by climate change. The magnitude of impact, however, reduced under the fossil fuel development pathway.

Changes in the production system, if adopted, will mitigate the increased future climate impacts to result in a reduction in the proportion of households vulnerable to 36% - 48% and a reduction in poverty by up to 5% and 3% under the sustainable and fossil fuel pathways respectively.

Adaptation

A longer crop life cycle is sufficient to reduce the negative impacts of climate change on the cereals, especially maize. Peanut yield would also increases but at lower magnitude. At least 50% of households may adopt use of heat tolerant variety resulting a reduction in poverty rate by 25% under both sustainable and fossil fuel driven agricultural development pathway pursued.

Authors: ***MacCarthy D.S., Valdivia R., Anaglo J., Madajewicz M., Clottey J., Adiku S., Amoah A.B., Amoako K.K., Quist E., Botchway V.A, Klutse N.A.B., Mutter C. & Rosenzweig C.***

2050s Climate Projections

Climate in Navrongo is likely to be variable with reduced rainfall events and higher temperatures

+1.9 to 2.7°C

Variable Rainfall: An increase of up to 10% in total amounts is expected while the number of rainy days would reduce by 13%.

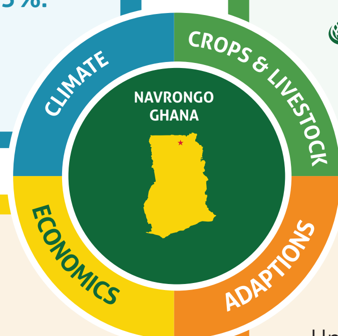
2050s Productivity Projections

Changes in climate could lead to:

Maize
In future farming systems characterized by higher input levels, maize continuous to be negatively affected by climate change.

Sorghum
Remains relatively less negatively impacted by climate change

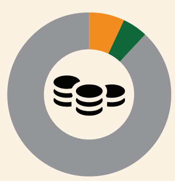
Peanut
Always benefits from climate change



2050s Economic Projections

Under current production systems, between 48 and 59% of households are vulnerable to climate change

Under current production system, poor households could increase by up to 7% due to climate change.



With sustainable development, about 40% of households will be vulnerable to climate change in the future

With sustainable development poverty rate could **decline** by **up to 5%**

2050s Adaptation Projections

Under future production systems, between 30 and 47% of households are vulnerable to climate change

Cereal Productivity
Using maize and sorghum with longer life cycle will improve yield and reduce negative impact of climate change

Peanut Productivity
Peanut also benefits from heat tolerant varieties but at a lower magnitude.

Improved Livelihoods
Adaptation will increase net farm income and reduce poverty in Navrongo.

48 - 56% of households could possibly **benefit** from adaptation to climate change.

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For more information on the AgMIP-CLARE Project, visit http://agmipimpactsexplorer.
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POLICY BRIEF

OCTOBER 2021

Effective Climate Change Adaptation Planning in Ghana: The role of AgMIP for improved Climate Resilience

KEY MESSAGES

- **Research that links** Ghana's national and regional policy development and implementation can better support climate change adaptation at each scale.
- **Evidence-based research outputs** can enhance policy decision making processes for more efficient targeted investments and implementation of climate change adaptation strategies.
- **A robust adaptation planning system** includes the assessment of vulnerabilities anticipated and experiences to establish best policies and technological interventions at farm and landscape scales for key agricultural production systems.
- **Forward looking methods** like the AgMIP Regional Integrated Assessment (RIA), are essential to**:**
    - Inform policy and investment decisions on appropriate adaptation strategies.
    - Identify potential vulnerable groups under climate change.
    - Provide evidence for prioritization and budgeting for implementation.
- **Capacity building** in forward-looking methods and tools in Ghana's education and technology initiatives will strengthen national and local policymaking for better agricultural outcomes at a range of scales, even with changing climate.

Context

The agriculture sector is critical for the economies and livelihoods of many, and its performance has a major influence on food security. For effective implementation, a robust adaptation planning process requires analysis of vulnerability to climate change and adaptation planning options.

The economic feasibility of climate change adaptation strategies for different farming systems and the populations under different conditions at the local level has however, been inadequately assessed. Information is typically aggregated at the global level or for supra-national regions. Information on climatology, climate projections, vulnerabilities, and adaptation options at these levels may be quite different from those that apply to a particular district within a country. The population of farms in the agricultural production systems is diverse in terms of the socio-economic situation which impacts differently on their productivity. Any given adaptation option will therefore perform differently in different localities.

The analysis of key agricultural systems is needed to develop, test and implement adaptation strategies at regional and farm levels which can in turn, inform and support policy decision making and planning at the national level.

The **AgMIP-CLARE Project**[1] links regional analyses carried out under the previous AgMIP activities with national climate change planning in Ghana. Working closely with key stakeholders, the project brings new methods to address information gaps that have hindered stakeholders from linking research and policy in the past.

[1]AgMIP-CLARE is a research project aiming at investigating climate change impacts and adaptation options in smallholder farming systems. The work expands and extends the previous AgMIP work to contribute to adaptation and resilience decision-making at the national scale. This is to implement evidence-based and thus more effective National Adaptation Planning for climate change, as well as provide methods to better link Ghana's national and regional adaptation efforts.

Authors: MacCarthy D.S., Valdivia R., Anaglo J., Madajewicz M., Clottey J., Adiku S., Amoah A.B., Amoako K.K., Quist E., Botchway V.A, Klutse N.A.B., Mutter C. & Rosenzweig C.

A baseline survey and stakeholder interviews revealed several challenges in climate policy implementation, and areas for further research using collaborative methodologies like those advanced by AgMIP.

Challenges to Climate Policy Implementation

- Low government investment in research and limited evidence-based information has led to inadequate use of scientific information for policy development and implementation.
- Inadequate dissemination of policy documents at the national and sub-national levels and low awareness of contents of policy proposals.
- High attrition rate of personnel at the local level where policies are implemented, limiting capacity building in climate change adaptation processes.
- Lack of continuity in executing development plans in the agricultural sector, due mainly to change in political administration.
- Limited assessment of climate vulnerabilities and adaptation options, and climate change impacts on local agricultural systems.
- Inadequate data to support policy decision making. There is the need to move away from assessment approaches that rely on aggregate data or individual crop productivity to disaggregated data on a whole farm that captures the heterogeneity in the population of farms.
- Inadequate modelling expertise and models to assess climate change impacts on the crops of interest to the Ghanaian or tropical regions. Models developed in higher latitude countries usually do not address agricultural challenges characteristic of many tropical regions.
- Socio-cultural barriers that limit the adoption of adaptation options. Often the barriers are location-specific, thus the need for approaches that capture the unique issues at the local level.

Research Needs

- Establish rigorous processes by which adaptation strategies can be assessed for their effectiveness, including for whom and under what conditions.
- Demonstrate how to measure the cost of adaptation - including in comparison to not adapting - to create a robust case for investment in adaptation strategies.
- Identify the contents of information packages that are needed to guide risk management and adaptation decisions in specific contexts, and how they can be assembled for use.
- Mentor local researchers, technicians, and stakeholders on appropriate ways to utilize climate information so they can help guide investment decisions, especially among farmers and farmer businesses.
- Develop climate infrastructure and services by sharing data for the continuation of research and policy interactions.
- Develop high-quality seasonal predictions as well as methods that can guide decisions on farm activities by a range of actors, including farmers, and connect information about climate variables to decisions.

The **AgMIP** Approach can support Ghana's **Climate Policy, Agricultural Development,** and **Implementation** by:

- Providing **evidence-based research methodology** that generates results to adequately support the National Adaptation Planning process. This uses current, and forward-looking, scenarios that are co-developed by scientists and stakeholders, as well as other Regional Integrated Assessment tools.
- Contributing to provision of **reliable quality data** on climate projections.
- Providing **information on economic feasibility** of potential climate change adaptation strategies.
- Conducting **assessments at the regional (sub-national) level** that capture how climate change, policy or technological interventions may impact farming systems and farmers livelihoods. These kinds of information are required to support decision making at national level.
- Contributing to **capacity building** in the use of tools and methodologies required for forward looking climate change adaptation analysis and planning processes.

Key Drivers for Improving Research-Policy Linkages

COMMUNICATION

- Creating an appropriate platform for climate change policy makers and scientists will ensure effective communication. Scientists can use media engagement, workshop for stakeholders, use visualization and information materials (e.g., policy briefs, infographics, audio-visuals, posters) to discuss/validate their work. Personal engagement and networking among researchers and policy-makers can enhance effective communication of research to policy, including feedback on the direction of research and products.

ENGAGE POLICY MAKERS

- Regularly engaging policy makers in the research process creates shared learning and common interest, and opportunities to co-produce knowledge, as well as trust in the information. Knowledge jointly produced through deliberative dialogue with researchers, policymakers, and local communities provide new viewpoints and contextualize findings. Stakeholder dialoguing also contributes to more effective adaptation to climate impacts by improving the relevance and robustness of research results.

CAPACITY BUILDING

- Creating an appropriate platform and environment for climate change policy makers and scientists will ensure effective communication. Scientists can use media engagement, workshop for stakeholders, and visualization and information materials (e.g., policy briefs, infographics, audio-visuals, posters) to discuss/validate their work. Personal engagement and networking among researchers and policy-makers can enhance effective communication of research to policy, including feedback on the direction of research and products.

NEXUS OF CLIMATE CHANGE AND DEVELOPMENT

- Climate change adaptation can be enhanced if there is strong political commitment. Climate change adaptation needs to be a priority on the policy agenda instead of focusing on investment that yield short-term benefits. Key government ministries (e.g., Ministry of Finance (MoF), Ministry of Environment Science Technology and Innovation (MESTI), and Ministry of Food and Agriculture (MoFA)) responsible for finance and development planning could lead initiatives to strengthen research-policy linkages.

INVESTMENT IN CLIMATE CHANGE RESEARCH

- Investment into climate change adaptation research from domestic sources is currently inadequate, limiting funding largely from international sources. Public and private sector investments in climate change adaptation research and development would be able to generate outputs that lead to increased understanding of the potential effects of climate change. Such investments must not be a one-time issue but should be mainstreamed or integrated into the budgetary processes of both the public and private sector players

Key Recommendations

The following actions are therefore needed to inform national planning, provide inputs, and engage stakeholders to link research and policy:

- **Strengthen partnerships** between state and non-state actors for awareness creation on climate adaptation action building capacity to develop fundable proposals.
- Extend the **use of forward-looking methodologies** such as the AgMIP Regional Integrated Assessment (RIA) tool to major agricultural areas to enhance policy decision making. This will help determine the most appropriate places to allocate scarce resources for climate change adaptation activities to achieve maximum returns.
- **Public and private sector partnership investment** in climate change adaptation research to address inadequate funding.
- **Continuous training** of stakeholders to understand and appreciate the outcomes of RIA tools and hence, develop the confidence to utilize outputs in their policy planning and decision making.
- **Train and support scientists and key stakeholders** on the use of the AgMIP RIA tools to support policy development.
- Build systems to enhance the development of **multidisciplinary local expertise** in the development of future decision support tools.

READING MATERIAL

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Acknowledgements

This work was carried out with financial support from the UK Government's Department for International Development and Foreign, Commonwealth & Development Office, as well as the International Development Research Centre, Ottawa, Canada Climate and Resilience (CLARE) Program; via the Agricultural Model Intercomparison and Improvement (AgMIP) 'A-Teams' project award #109204-001 to Columbia University, including support of seven additional AgMIP partners. This publication has not been peer reviewed. Any opinions stated in this publication are those of the author(s) and are not necessarily representative of or endorsed by the partners.

For more information on the AgMIP-CLARE Project, visit http://agmipimpactsexplorer.

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POLICY BRIEF

NOVEMBER 2021

National agricultural development pathways influence climate change impacts on smallholders' livelihoods in Navrongo, Ghana

KEY MESSAGES

- Agricultural development can enhance the overall livelihood of farmers by 2035 by improving income and reducing poverty and food insecurity. The magnitude of benefit depends on selected agricultural pathways.
- A *Sustainable Development (SD)* pathway may result in a **greater** improvement of farmers' livelihoods compared to a *Business as Usual (BAU)* or a *Fossil Fuel Development (FFD)* - based pathway.

Context

Ghana's National Adaptation Plan (NAP) framework emphasizes the need to assess the vulnerabilities of key economic sectors to climate change in order to identify appropriate adaptation options. The Agricultural Sector, which is highly exposed and vulnerable to adverse climate and environmental impacts, significantly contributes to livelihoods of the majority of the rural population.

A study was carried out under the **AgMIP-CLARE Project**[1] in Navrongo - a semi-arid agro-ecology in Ghana - using the framework of the AgMIP's *Regional Integrated Assessment* (RIA; Antle et al. 2015).

This policy brief summarizes the study, describing the vulnerability of the agricultural sector and adaptation strategies for **three** plausible agricultural development pathways, co-generated by stakeholders (including scientists):

- Business as Usual (BAU)
- Sustainable Development (SD)
- Fossil Fuel Development (FFD)

Maize farms in Tamale in 2012

The AgMIP RIA has key features that makes it appropriate for climate change impact and adaptation assessments:

1. Driven by iterative stakeholder interactions;
2. Analysis of farming *systems* (not just crops);
3. Trans-disciplinary, bio-physical and socio-economic;
4. Multi-scale level (using field, farm, region, and global data and models);
5. Linked, multi-model methods, with
6. Distributional results such as impacts on poverty rates.

[1]AgMIP-CLARE is research aimed at investigating climate change impacts and adaptation options in smallholder farming systems. The work expands and extends previous AgMIP work to contribute to adaptation and resilience decision-making at the national scale. The result is evidence-based and thus more effective for National Adaptation Planning for climate change, with methods that better link Ghana's national and sub-national adaptation efforts. CLARE is the IDRC/FCDO Climate Adaptation and Resilience program.

Authors: MacCarthy D.S., Valdivia R., Clottey J., Adiku S., Anaglo J., Madajewicz M., Amoah A.B., Amoako K.K., Quist E., Botchway V.A, Klutse N.A.B., Mutter C. & Rosenzweig C.

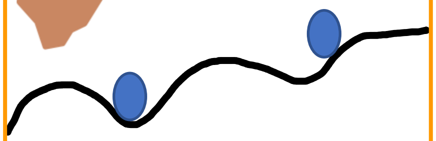
Three Co-Identified Plausible Development Pathways

Under the *current* production system, small-holder farmers in Navrongo have low levels of farm income, resulting in high levels of poverty and food insecurity. Stakeholder interactions identified **three** plausible *future* development pathways:

Business As Usual (BAU), Sustainable Development (SD) and Fossil Fuel (FFD) driven pathways

National RAPs

Business as usual



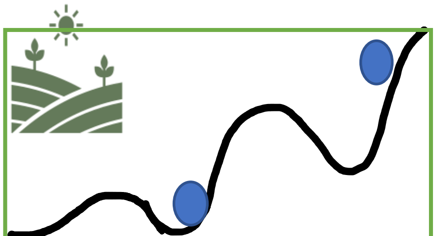
Agricultural development

Agricultural system is characterized by slow and inconsistent productivity growth as well as low adaptive capacity due to inadequate commitment of resources to implement appropriate policies.

Climate policies

Inadequate resource allocation coupled with leakages lead to marginal and erratic investments and low diffusion of climate smart agricultural technologies.

Sustainable development



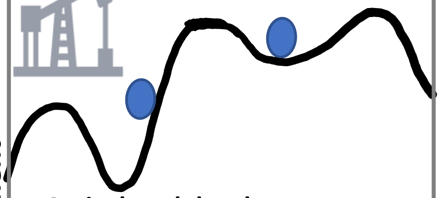
Agricultural development

Agricultural system is modernized and characterized by continuous growth and resilience through private sector-led investments into appropriate technologies that balance economic growth and ensure environmental sustainability.

Climate policies

Massive investments in environmentally friendly infrastructure and climate-smart agricultural technologies through efficient private sector-led mobilisation of resources from green climate funds.

Fossil Fuel driven development



Agricultural development

Agricultural system is vigorously intensified and up-scaled with gross disregard for environmental sustainability resulting in rapid short-term economic growth.

Climate policies

Massive industrialization with carbon intensive energy and technologies as the backbone, with little regard and commitment to environmental sustainability.

Regional Implementation

Business as usual

Implementation of national agricultural policies at the sub-national level challenged by inadequate resources due to competing short term needs.

Thus, subsistence farming persists with limited use of appropriate external inputs due to weak institutional support structures leading to inefficient use of resources and low enforcement of environmental standards.

The design and implementation of climate change adaptation strategies are challenged by low and adhoc investments.

Sustainable development

Implementation of national agricultural policies at the regional level spurred by adequate investment led by private sector participation.

Thus, strong institutional coordination results in efficient dissemination and utilization of resilient agricultural technologies with effective enforcement of environmental standards.

Climate policies and investments enable effective design and implementation of appropriate strategies that promote resilient production system.

Fossil Fuel driven development

Implementation of national agricultural policies at the regional level spurred by massive investments led by private sector participation.

Large scale farms dominate the landscape supported by investments into technologies that support aggressive intensification. Low priority for enforcing environmental standards.

The design and implementation of climate change adaptation strategies disregards the mitigation pillar, thus reducing the adaptive capacity of the production system.

The response of the farming system to each of the development pathways on smallholder farms in Navrongo was assessed.

The regional Representative Agricultural Pathways (RAPs) provided parameters for bio-physical and economic models to simulate the impacts of climate change and adaptation on farmers' livelihoods using the AgMIP RIA methodology.

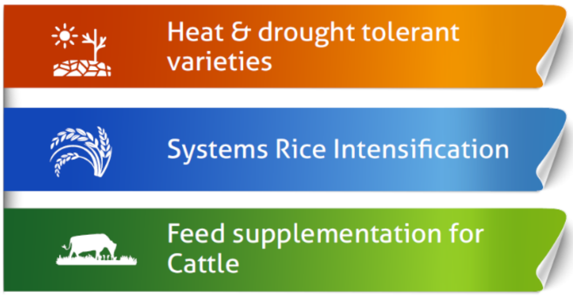
Co-Developed Adaptation Strategies

The government provides subsidies on improved, climate resilient seeds to enable the uptake of existing adaptation strategies.

Groundnut (peanut) remains a very important crop in the farming system within the study area as it benefits from climate change owing to CO_2 fertilization, lessening the impact of climate change on net farm returns, poverty rate and food insecurity of smallholders in Navrongo.

All three future plausible agricultural development pathways (BAU, SD & FFD) result in increased income as well as reduced poverty and food insecurity compared to current agricultural production system under current climate.

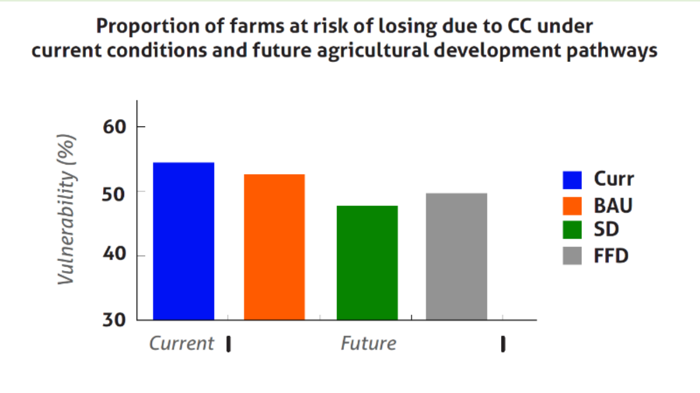
Adaptation package

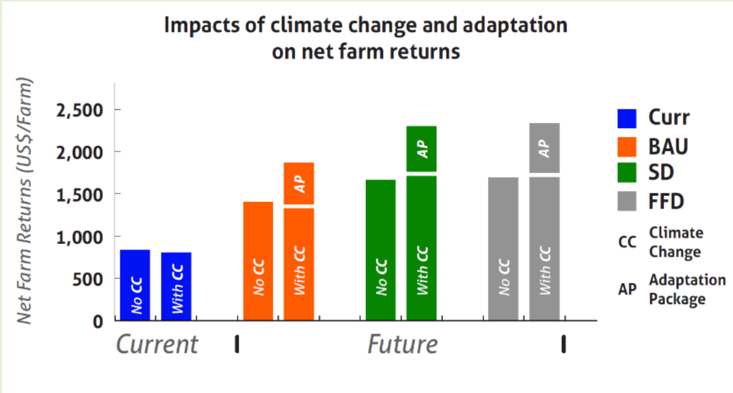


Stakeholder co-generated adaptation packages

With projected climate change:

- BAU agricultural pathway **reduced** the income of smallholders and **increased** poverty and food insecurity.
- SD pathway **improved** income, leading to **reduced** poverty and food insecurity (although large proportion of farms still remain vulnerable to climate change).
- Under the FFD pathway, there was **no change** in income.





Left diagram: Impact of climate change on farm vulnerability at present and in the future production systems. Current Production (Curr), Business as Usual (BAU), Fossil Fuel Driven Development (FFD) and Sustainable Development (SD). Right diagram: Impacts of climate change (CC) and adaptation (AP) on income, under current conditions and for three future agricultural pathways.

Future production system with climate change

- Policies and interventions under the SD pathway help farmers to be more resilient to climate change, compared with BAU and FFD scenarios.
- Vulnerability to climate change remains significant under all pathways, highlighting the need for adaptation strategies that target improved farm productivity, income and household livelihoods.

Future production system with climate change and adaptation

High adoption rates of proposed adaptation strategies would lead to:

- Significant increase in farm net returns under the SD and FFD pathways compared to the BAU pathway
- Decreased poverty rate and food insecurity with the adoption of the adaptation technologies

The adoption of the tested adaptation packages led to projected increases in income and declines in poverty and food insecurity across the three development pathways.

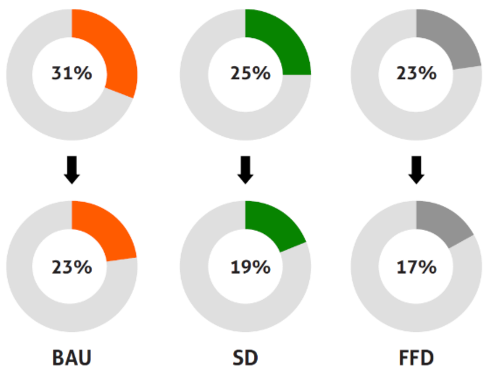
Poverty and vulnerability (food insecurity) were highest along the BAU pathway.

Poverty and vulnerability lessen along the FFD and SD pathways.

Conclusion

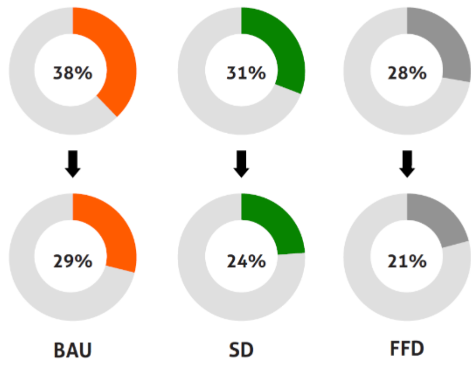
Integrated forward looking assessments that are stakeholder-driven and include multiple climate and crop models across multiple farms provide an important science-based source of evidence for policy, decision making, planning and priority setting. This methodology provides an approach that has been recommended by stakeholders to be scaled up to important crop producing areas in the country, to provide more input to the NAP processes.

Poverty declines to 23%, 19% and 17% under BAU, SD and FFD pathways, respectively.



The adoption of adaptation packages leads to a decline in poverty and food insecurity for all three development packages*

Food insecurity declines to 29%, 24% and 21% under BAU, SD and FFD pathways, respectively.



**The FFD pathway presents additional environmental trade-offs such as degradation of the natural resource base and increasing greenhouse gas emissions that were not assessed in this study.*

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AgMIP

Sénégal - Adaptation au changement climatique:

Quelle(s) contribution(s) le projet AgMIP-CLARE peut-il apporter à l'intégration de la recherche dans les Plans Nationaux d'Adaptation ?

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MESSAGES CLÉS

- La planification nationale d'adaptation aux changements climatiques et les processus d'action pour l'agriculture sont au coeur des efforts, à l'échelle du globe, aux visant à améliorer la sécurité alimentaire. Ils sont déterminants pour réduire la pauvreté et améliorer les moyens de subsistance dans les pays en développement.
- La création de partenariats et la consolidation de ces collaborations et réseaux, par le biais des communautés de pratiques (CdP) sont essentielles au succès des processus de planification puisqu'elles se basent car sur l'expertise techniques dans différents domaines afin de favoriser les échanges et la conversion des résultats de la recherche en connaissances pratiques et en Politiques.
- Les projets de recherche et de développement ont contribué à la sensibilisation au changement climatique et aux vulnérabilités du secteur agricole à la variabilité climatique. Ceci s'est traduit par des changements de politique.
- Au niveau national, plusieurs institutions participent au processus d'adaptation aux politiques de changement climatique. Néanmoins, par défaut d'actions concertées, la prolifération d'interventions redondantes, ralentit les efforts et nuit aux investissements consacrés.

- Par ailleurs, la compréhension des niveaux de vulnérabilités et des options d'adaptation reste limitée, et ce tout particulièrement auprès des décideurs locaux
- Les participants à l'étude[1] ont convenu que l'adaptation aux changements climatiques fait face à des défis par rapport à son défaut d'intégration dans les politiques publiques. Ce qui entraîne bien souvent un système de gouvernance inefficace, sans cadre existant qui devrait centraliser toutes les parties prenantes et des politiques éparses.
- Ces défis concernent principalement : - la formulation d'une politique nationale ne reflètant pas adéquatement les différences dans les défis et les conditions à travers le pays, - une communication insuffisante entre les niveaux local et national, ainsi que des connaissances et capacités jugées insuffisantes au niveau local pour (1) s'investir dans la planification du changement climatique, (2) influencer cette planification au niveau national et (3) mettre en œuvre des stratégies d'adaptation.

1 Les données recueillies proviennent d'un rapport de référence produit pour le Projet d'intercomparisation et d'amélioration des modèles agricoles (AgMIP), afin de soutenir la planification nationale des changements climatiques pour l'agriculture. Des entrevues téléphoniques enregistrées et transcrites sur des enregistrements audio, des singes d'enquête et des examens de documents nationaux ont été menés à l'aide des trois sources suivantes : 10 intervenants sélectionnés qui participent aux processus de planification; 18 acteurs agricoles dans les secteurs agricoles et; L'équipe de recherche de l'AgMIP, qui a effectué un examen approfondi des documents nationaux pertinents.

INTRODUCTION

Le changement climatique est l'une des préoccupations majeures de ce siècle en raison notamment de l'impact et des conséquences importantes que les crises climatiques ont sur les moyens de subsistance. En Afrique de l'ouest, l'agriculture est un secteur hautement prioritaire dans la planification des changements climatiques. Les conditions climatiques défavorables ayant conduit à une diminution des rendements céréaliers, comme le mil, avec une baisse comprise entre 10 et 20% sur la période 2000-2009 (Sultanet al., 2019[1]), ont fortement contribué à cette prise de conscience de la vulnérabilité du secteur agricole aux variabilités climatiques.

Au niveau national, les décideurs ont démontré un engagement croissant en faveur de la planification des changements climatiques, qui se matérialise à travers un appui aux projets d'adaptation au changement climatique dans l'agriculture. Toutefois, leur niveau d'engagement et d'appropriation semblent encore insuffisants. La compréhension de la vulnérabilité climatique et des options d'adaptation demeure limitée, notamment au niveau local.

La production de données probantes constitue de facto un point de départ important pour guider les décideurs.

La recherche a développé plusieurs outils qui favorisent la compréhension de la vulnérabilité climatique et qui ont su capter l'attention et généré un engagement des acteurs pour une lutte plus efficace contre les changements climatiques.

Les processus d'influence au niveau de la planification nationale requièrent néanmoins plus d'efforts que la seule présentation de résultats sur les changements climatiques. Il est ainsi essentiel de saisir la pertinence des contextes (politiques, socio-économiques). Et également d'impliquer les principaux acteurs dans

1 climatique historique dans deux modèles de cultures. Rapports scientifiques.

tous processus de recherche.

C'est dans ce contexte que le projet AgMIP CLARE[2] mené au Ghana, au Sénégal, au Zimbabwe, suggère que de nombreuses décisions concernant la gestion du changement climatique et la mise en œuvre des adaptations ne sont prises qu'au niveau des communautés par le gouvernement local, les organisations de la société civile, les agriculteurs, les transformateurs, les distributeurs et les ménages. Ces acteurs locaux dont les expériences et les solutions locales ne parviennent pas assez à pénétrer les instances nationales, ont plus de difficultés à être sufisamment entendu pour que leurs solutions soient intégrées dans l'élaboration des politiques nationales. Ces acteurs locaux souhaitent profiter d'interactions plus soutenues pour une meilleure imprégnation des politiques et pratiques nationales par les circonstances et contexte locaux.

A ses débuts, le projet AgMIP, avait comme principaux objectifs pour l'engagement des parties prenantes de : (a) d'intégrer les points de vue des parties prenantes dans les modèles agricoles, (b) d'élaborer des scénarios futurs et d'affiner et de (c) partager les conclusions et les extrants du projet.

2 [1] AgMIP CLARE est un projet de recherche visant à étudier les impacts du changement climatique et des options d'adaptation dans les systèmes agricoles des petits exploitants. En outre, il cherche à aider les décideurs à utiliser les preuves pertinentes générées par l'analyse des conditions qui peuvent augmenter leur adoption. Cet objectif a donné lieu à plusieurs interactions avec les intervenants (KII, atelier, réunions) pour comprendre pour l'AgMIP, et les projets de recherche en général, le contexte national et les changements qu'ils pourraient appliquer pour mieux utiliser leurs données probantes par les décideurs.

PRINCIPAUX CONSTATS

Une des thématique récurrente de cette étude réside dans un manque tangible de connaissances et de compétences soutenues au niveau local, où des adaptations sont mises en œuvre.

- Les gouvernements locaux, la société civile et les communautés influencent les processus de planification et d'action en matière de changement climatique, car les plans d'adaptation sont mis en œuvre au niveau local. La mise en œuvre des stratégies d'adaptation aux changements climatiques pour l'agriculture résulte, en partie, de la concertation, de la coopération et de l'adhésion du gouvernement local, des communautés et des agriculteurs.
- La transmission de l'information entre les niveaux local et national doit être améliorée. L'élaboration des politiques et une meilleure répartition des ressources au niveau national feraient progresser l'adaptation plus efficacement grâce à la fourniture de données et autres informations de qualité sur la diversité des conditions et des besoins exprimés au niveau local. Les pratiques d'apprentissage par l'exemple dans des conditions différentes au niveau local seraient également à généraliser. Les décideurs locaux souhaitent être mieux informés des politiques et ressources disponibles au niveau national.
- Le niveau local fournit au niveau national des données clés sur les défis qui doivent être relevés notamment par rapport aux approches les plus abouties et qui pourraient guider les efforts d'adaptation. Les coutumes locales doivent être prises en compte dans l'élaboration de la politique nationale.
- Les documents politiques et stratégiques sont importants non seulement parce qu'ils établissent les priorités nationales, soutenant planification et mises en œuvre.
- Le volet comportementale est essentiel pour prédire les impacts. Son développement nécessite une estimation empirique des impacts. De nombreuses personnes interrogées ont exprimé le besoin de mener une recherche empirique locale. Les participants mentionnent en effet que la recherche sur la vulnérabilité et en particulier sur l'adaptation doivent permettre de tester les adaptations dans les communautés, d'apprendre de leurs expériences et de fournir des données probantes à même d'orienter le transfert vers d'autres domaines et l'intensification des approches efficaces dans la zone d'étude et au-delà.
- Plusieurs participants ont estimé que la planification de l'adaptation devrait être fondée sur des données probantes qui, à date, sont inadéquates. Certains participants suggèrent que la recherche devrait être menée de manière participative. Car selon elles, pour l'organiser efficacement, la recherche autour des principaux problèmes identifiés doit se faire avec les décideurs afin qu'ils en cernent mieux les objectifs, les capacités et les contraintes des acteurs , selon le contexte et la nature du défi à relever.

IMPLICATIONS POLITIQUES

- L'action politique devrait mettre l'accent sur le renforcement des capacités des parties prenantes locales et nationales concernées. Et ce afin de mieux traiter les résultats de la recherche et toutesles informations techniques pour une prise éclairée de décisions.
- Une partie du besoin de renforcement de capacité au niveau local peut être satisfaite par la fourniture pérenne d'un service d'information sur le climat. Une demande d'allocation de ressources au développement de ces services transparaît dans cette étude .
- La recherche pourrait évaluer les régions les plus représentatives du pays, en définissant dans quelles conditions environnementales et socio-économiques des composantes spécifiques de l'information sont différentes, et pour lesquelles les décideurs devraient recevoir des conseils adaptés. Cette requête s'applique plus particulièrement aux projections climatiques, à l'analyse des vulnérabilités actuelles et des modèles de vulnérabilités futures, ainsi qu'à l'analyse des options d'adaptation.
- L'efficacité des approches d'adaptation doit être étudiée au niveau local. Les études empiriques des impacts des approches d'adaptation produisent des preuves qui peuvent être utilisées pour développer des modèles à mêmes de prédire les impacts des approches d'adaptation dans des scénarios prospectifs (conditions futures). La plupart des modèles actuels d'impacts d'adaptation omettent la composante comportementale qui détermine le profil des adopteurs des options et stratégies d'adaptation. Ou, comment leur comportement se répand au sein de la population à partir des premiers adopteurs. Ou encore comment les agents mettent en œuvre l'adaptation et elle affecte d'autres parties du système économique

CONCLUSION & PERSPECTIVES

« Je pense qu'il y a beaucoup de recherche-action à faire à ce niveau : aider les communautés à s'adapter au changement climatique. Mais ne vous contentez pas de faire des études et de partir; il faut expérimenter avec tout un village pour voir les résultats sur le terrain. Ce que nous voyons souvent, c'est de la recherche par projet; une équipe vient, fait des recherches pour un projet et s'en va. Tant que nous continuerons ainsi, nous ne serons jamais en mesure de faire face au changement climatique avec nos agriculteurs et d'autres. »

Une personne interrogée du Sénégal

Parmi les autres priorités figurent la recherche qui soutient le développement des capacités d'adaptation des agriculteurs et des services de vulgarisation dans les trois pays et l'intégration des connaissances autochtones dans la recherche.; En outre, l'adaptation exige que les agriculteurs et les autres décideurs adoptent de nouvelles pratiques. Et qu'ils comprennent quelles options et stratégies peuvent être recevables et replicables pour les décideurs. Il s'agirait par ailleurs de parvenir à déterminer le type d'interventions susceptibles de faciliter l'adoption de pratiques innovantes par les décideurs.Tout ceci nécessite des recherches plus ciblées (locales) et avec le concours de plus de décideurs.

Rapprocher les décideurs politiques et les chercheurs pour formuler de meilleurs plans nationaux d'adaptation

L'expérience du projet AgMIP-CLARE au Sénégal.

Auteurs : Ibrahima Hathie (Economiste – IPAR), Diamilatou Kane (Assistante de recherche - IPAR), Ahmadou Ly (Socioéconomiste - IPAR), Laure Tall (PI - IPAR), Roberto Valdivia (PI - Université d'Oregon).

MESSAGES CLÉS

- Les efforts d'adaptation ne pourront être efficaces sans une évaluation approfondie de la vulnérabilité des populations considérées et une prise en compte effective des options d'adaptation pertinentes dans différentes conditions (spatiales, socioéconomiques).
- Au niveau national, de nombreuses institutions sont impliquées dans les processus politiques d'adaptation aux changements climatiques. Toutefois, elles opèrent le plus souvent en vase clos. Cette tendance engendre une duplication des efforts (et des moyens) se soldant par des interventions inefficaces.
- L'insuffisance de données et le manque de mécanismes de partage de ces données entravent le développement de stratégies d'adaptation efficaces au niveau local.
- Le gouvernement et ses partenaires devraient davantage appuyer la recherche afin de relever ces défis relatifs à l'évaluation des vulnérabilités des populations locales et d'améliorer les politiques nationales d'adaptation.
- Les données probantes montrent que la recherche génère des connaissances pertinentes pour les plans et les programmes nationaux d'action climatique.

Le projet AgMIP CLARE tente d'apporter un éclairage nouveau en soutenant les engagements nationaux en faveur de l'adaptation au changement climatique dans le secteur agricole. En évaluant les impacts du changement climatique et des stratégies d'adaptation sur les systèmes agricoles actuels et futurs, le projet contribue à la prise de décision éclairée dans l'agriculture. Sur la base d'une méthodologie combinant des modèles (climatiques, agrononomiques, économiques) et des interactions avec les parties prenantes, le projet prône une approche inclusive visant à atteindre les objectifs de sécurité alimentaire aux niveaux national et régional grâce à des systèmes agricoles productifs et durables.

INTRODUCTION

Le changement climatique est un défi pressant compte tenu de ses conséquences importantes sur les moyens de subsistance des agriculteurs au Sénégal.

Les stratégies d'adaptation aux changements climatiques font partie des solutions identifiées pour soutenir les populations vulnérables. De nombreux projets intègrent des recherches qui abordent et traitent des questions climatiques et identifient des options d'adaptation encourageantes.

Malgré ces progrès notables d'un point de vue de la recherche, des défis persistent et ralentissent la mise en œuvre efficace des stratégies identifiées.

En effet, les politiques et la recherche semblent avoir des orientations différentes et fonctionnent selon des logiques calendaires opposées. Il devient nécessaire et urgent d'œuvrer à combler ces écarts et à renforcer les collaborations entre les chercheurs et les décideurs politiques.

ENCADRÉ 1 : AgMIP en bref

AgMIP (Agricultural Model Intercomparison and Improvement Project) est un projet de recherche qui étudie les impacts du changement climatique et propose des options d'adaptation des systèmes agricoles des petits exploitants. Il vise également à mieux soutenir la formulation des politiques nationales d'adaptation à travers la production de données probantes et le renforcement des capacités des acteurs pour une meilleure utilisation des outils et des résultats de recherche du projet.

Le projet s'appuie sur une approche intégrée de modèles biophysiques et socioéconomiques de projection climatique pour évaluer, d'une part, les risques climatiques auxquels sont confrontés les systèmes agricoles et, d'autre part, l'impact des stratégies d'adaptation sur lesdits systèmes agricoles.

Par ailleurs, la démarche d'intervention du projet inclut une dimension relative à des interactions avec les parties prenantes (entretiens individuels, ateliers, réunions). C'est le cas des scénarios de prospective qui sont co-développés avec les parties prenantes pour caractériser l'évolution des futurs systèmes agricoles à l'horizon 2035.

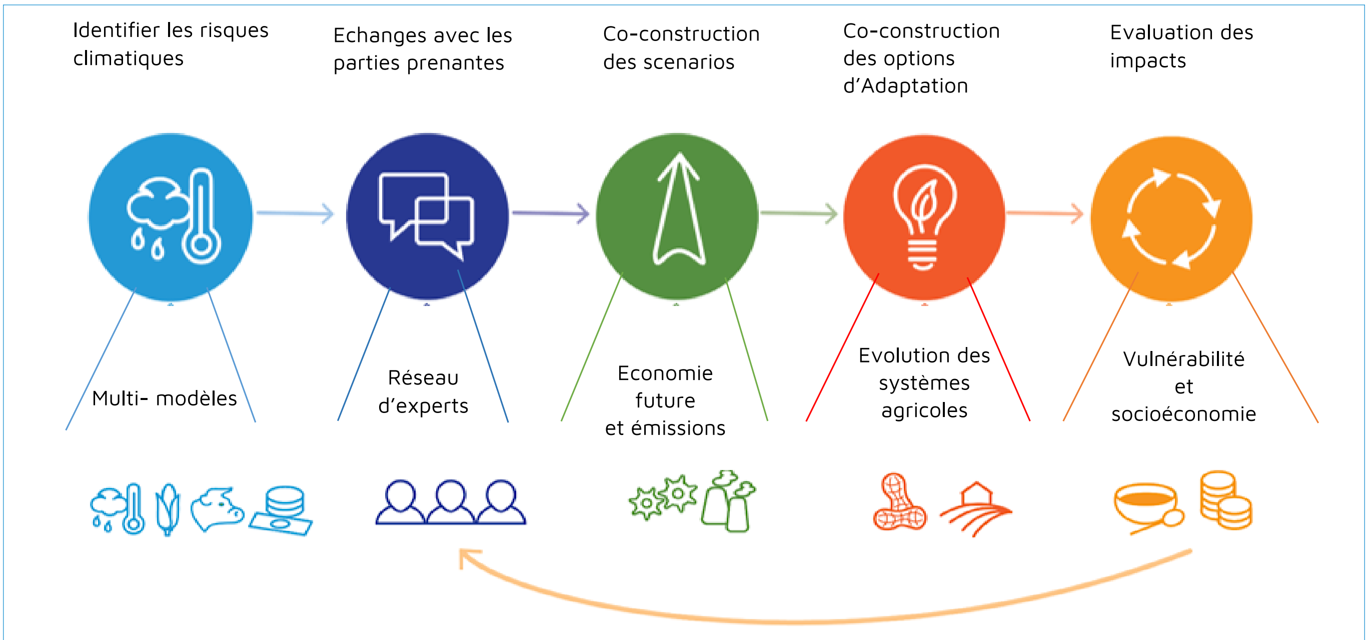
AgMIP et d'autres projets de recherche sont en mesure de comprendre le contexte national et d'analyser les changements requis qui susciteront l'utilisation efficace et cohérente des données probantes par les décideurs.

Les intervenants à un atelier organisé dans le cadre du projet AgMIP-CLARE ont confirmé qu'AgMIP propose des résultats pertinents qui guident l'action politique à l'échelle locale.
Les résultats de l'AgMIP ont été opportuns ; de multiples évaluations de la vulnérabilité sont actuellement mises en œuvre par différents projets pour éclairer les plans nationaux d'adaptation.

La collecte de tous les résultats contribuera à générer de nouvelles données probantes et à éclairer ces plans nationaux d'adaptation. De plus, l'approche d'évaluation intégrée et solide offre une gamme complète et diversifiée d'indicateurs climatiques, biophysiques et socioéconomiques.

L'approche AgMIP comprend un volet essentiel qui porte sur l'analyse socio-économique et qui fait défaut dans d'autres études de vulnérabilité. Les parties prenantes se sont montrées sensibles à cette composante.

Visuel 1 :



PRINCIPAUX CONSTATS

Le projet AgMIP CLARE, à travers les résultats de recherche obtenus et les différentes interactions avec les acteurs (décideurs, société civile, recherche, partenaires au développement), a pu aboutir à un certain nombre de constats :

1.Comprendre les besoins et les priorités :

La production de recherches répondant aux priorités des décideurs peut jouer un rôle central dans la mise en œuvre de politiques fortes. Pour y parvenir, il importe de tisser des liens étroits avec les principaux acteurs en vue de mieux comprendre les informations dont ils ont besoin et d'identifier les futurs domaines de recherche et d'interventions pertinents.

2. Situer l'importance des données évolutives aux niveaux local et national :

Les communautés locales sont les premières victimes des changements climatiques. Elles en subissent de plein fouet les dommages et demeurent tributaires de stratégies d'adaptation en majorité conçues au niveau national. Or, la prise en compte du niveau local dans l'élaboration des plans nationaux d'adaptation fait face à certains écueils dont le manque de données climatiques et d'éléments probants disponibles pour éclairer ces processus. Ainsi, il convient d'apporter plus de soutien à la recherche afin de proposer des stratégies d'adaptation pertinentes et répondant aux défis relatifs au changement climatique dans les zones considérées. Dans cette perspective, la recherche devrait interagir systématiquement avec les parties prenantes locales.

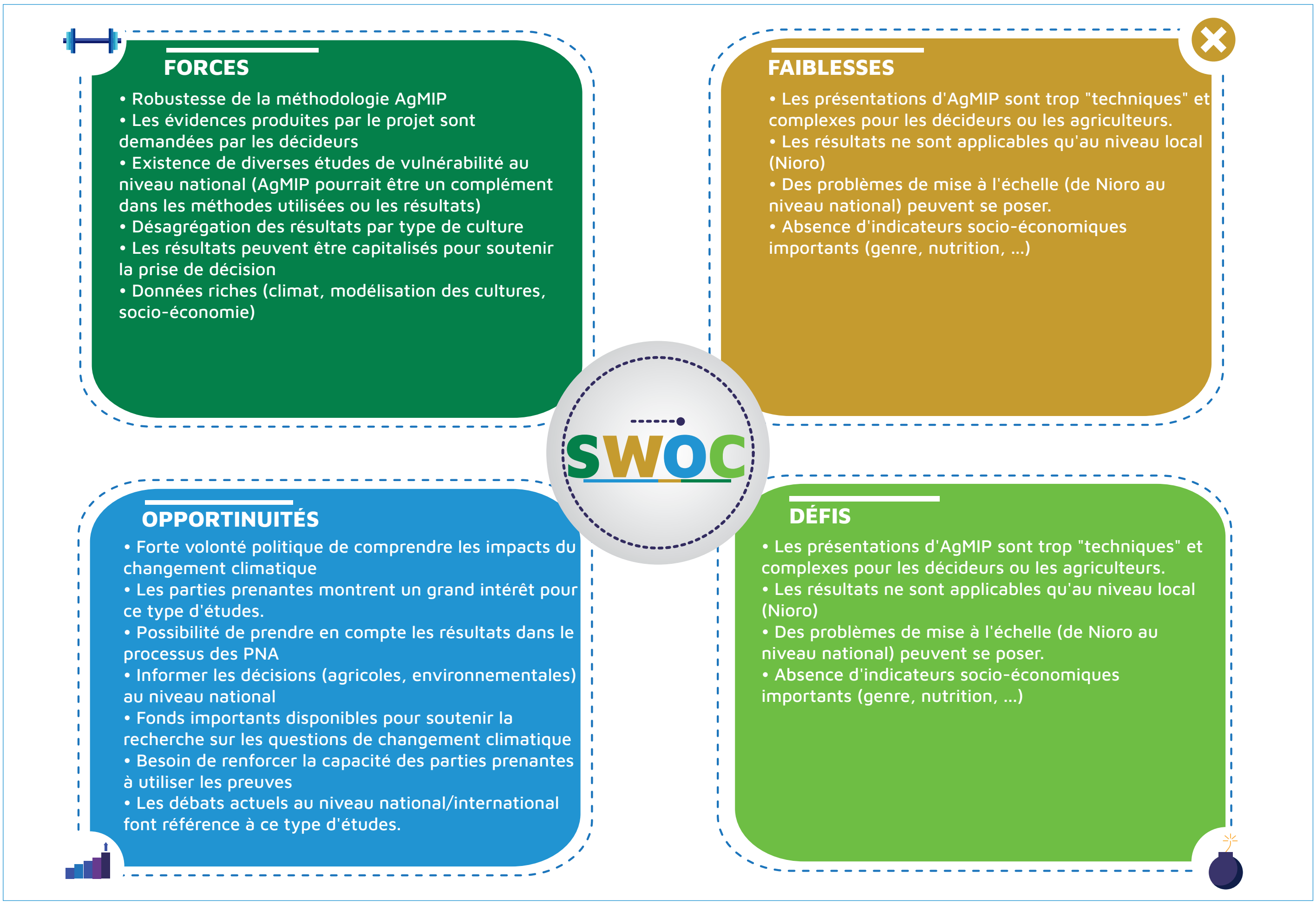
Les intervenants ont également identifié le défaut de communication des institutions de recherche chargées de produire des données accessibles au niveau local, désagrégées et de haute qualité, comme un point à améliorer.

3. Assurer la continuité du processus d'interactions entre chercheurs et décideurs :

Dans un contexte mondial qui encourage désormais davantage les approches pluridisciplinaires et intégrées, une vision court-termiste des relations entre chercheurs et décideurs pourrait entraver la mise en œuvre de politiques fondées sur des données probantes. Les organismes de recherche et les décideurs politiques devront apprendre à construire des passerelles interreliées pour atteindre leurs objectifs communs.

Á titre d'exemple de collaboration réussie, nous pouvons citer l'Inititiave Prospective Agricole et Rurale (IPAR) qui a été officiellement désignée par le ministère sénégalais de l'Environnement et du Développement Durable pour faciliter les interactions au sein de la communauté de pratique de l'adaptation au changement climatique. Elle est la résultante d'une collaboration à long terme, à travers laquelle l'IPAR a pu démontrer son expérience et rassurer sur son engagement à fournir des données probantes de qualité ainsi que des conseils et des services d'accompagnement.

Visuel 2 :



RECOMMANDATIONS & CONCLUSION

Á travers leur participation aux processus d'élaboration des documents de planification et de politique au niveau national, les scientifiques ont la possibilité d'œuvrer en étroite collaboration avec les décideurs politiques. Pour ce faire, ils doivent s'imprégner davantage des mécanismes de prise de décision au niveau national. Leur participation à ce processus serait par le fait même beaucoup plus bénéfique que la seule production des documents de planifcation.

Aussi, grâce à ce processus d'interactions (ou d'engagement), les chercheurs peuvent mieux informer les décideurs politiques et susciter plus de réflexions et de prises de positions claires de leur part.

Les décideurs politiques souhaitent acquérir plus de preuves de l'efficacité des stratégies face à différents scénarios et défis d'adaptation, en fonction des contextes locaux et des précoccupations des communautés, pour investir plus massivement dans les options d'adaptation.

La collaboration et la planification inclusive sont essentielles pour intégrer les informations disponibles, répondre aux besoins d'adaptation et tirer profit des expériences et des expertises, qui sont des éléments clés des processus de planification.

Une meilleure coordination entre la politique et la recherche est gage de succès car elle réduit les doubles emplois et les omissions et permet un usage plus rationnel et plus efficace des ressources (humaines et financières) limitées.

En effet, la planification nationale gagnerait à allouer davantage de ressources à la collecte, au stockage et à la gestion des ensembles de données à haute résolution spatiale et temporelle.

La recherche devrait aussi considérer la forte implication des décideurs tout au long du processus et des domaines d'études, afin de leur offrir une perspective différente en leur permettant de contribuer plus activement à la formulation des problématiques de recherche, d'en façonner l'approche, de proposer des réponses immédiates tout au long de la recherche et de contribuer de manière significative à la production des résultats.

Les chercheurs devraient connaître la structure de gouvernance de la planification de l'adaptation et collaborer avec les ministères concernés qui ont la capacité d'influencer les processus de planification nationale de l'adaptation.

Les chercheurs pourraient exercer plus d'influence s'ils s'engageaient auprès de consortiums existants et d'un large éventail de décideurs. Ils pourraient également envisager de s'associer à d'autres projets pour élargir leur champ d'expertise et coordonner les efforts visant à améliorer l'efficacité de ces projets en terme d'allocation des ressources.

Toutefois, certains points restent à améliorer. La méthodologie AgMIP et la fourniture de résultats bruts, jugés trop « techniques », ne facilitent pas une bonne appropriation de ces conclusions et résultats par les décideurs techniques et politiques. L'approche AgMIP n'inclut pas non plus certains indicateurs socio-économiques tels que les variables « genre » ou « nutrition » jugés indispensables pour une prise de décision éclairée.

D'où la nécessité pour l'AgMIP CLARE d'envisager une conception collaborative de ses méthodes et un partage de ses résultats, de manière à en favoriser l'appropriation.

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Working towards climate-resilient agricultural systems in Zimbabwe

Policy Brief 38
November 2021

Continued collaboration between policymakers and researchers is crucial for effective and dynamic climate-smart solutions

A farmer checks a new groundnut variety in Zimbabwe. AgMIP scientists consider groundnut as a climate-smart legume that is nutritious, soil-enriching and resilient to climate change. Inset: Government representatives at an AgMIP-CLARE Multi-stakeholder Workshop in Zimbabwe.

Key messages

- **Climate action is urgently needed:** Successive droughts and unseasonal climate events in Zimbabwe have already taken a toll on the country's economy. Climate projections indicate more dry conditions
- **Rainfed farming will be the worst hit:** Poverty amongst the population who depend on rainfed farming and are already living in harsh conditions will worsen

About AgMIP CLARE

Given the need for more effort to enhance climate action, the AgMIP (Agricultural Model Intercomparison and Improvement Project) CLARE (Climate Change Adaptation and Resilience) project provides tools, and information to better understand vulnerabilities of agriculture to climate change, and its performance under plausible future pathways, towards enhanced climate change adaptation and resilience. The collaboration with multi-scale and multidisciplinary experts and stakeholders to undertake and validate forward-looking research is set to guide actionable agriculture and climate change policy decisions.

ICRISAT INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS

AgMIP The Agricultural Model Intercomparison and Improvement Project

- **Growing awareness on importance of climate research:** Policymakers are aware that research-based climate change adaptation should be central to agricultural systems transformation
- **Proactive public-private response:** The government, development agencies and the private sector have started to diligently incorporate climate change adaptation, but there are gaps in linking local-specific climate change adaptation requirements to national-level policy decisions.
- **Need to address gaps through science-policy collaborations:** Continued dialogue and collaborations are crucial for effective and dynamic climate-smart solutions.

Linking science to decision-making: Research-based solutions for addressing gaps

- **Data and evidence** for context-specific effective responses, climate change impacts and suitable adaptation options can inform agricultural program design and align resources with activities
- **Forward-looking research** that helps understand climate projections, farming systems specific vulnerabilities and adaption impacts can enhance policy coordination and mainstream climate change adaptation in agriculture
- **Evidence-based assessments** can then more effectively support the rationale for climate finance and action
- **Capacity building** is critical for agricultural policy review and for the uptake of research processes and products. It is important to build human and institutional capacity in research, extension, climate services and especially for decision-makers to plan and guide research and use research outputs to inform decisions.

Introduction

Multiple challenges, including climate change and COVID-19, are affecting agricultural systems and livelihoods in Zimbabwe. An unstable macro-economic environment will exacerbate poverty, food insecurity and malnutrition, particularly among smallholder farmers.

Zimbabwe is projected to face drier conditions, with the Southern and Western regions of the country being more affected (World Bank, 2021). Increasing temperatures will worsen the current dry conditions, e.g. causing soils to dry up quicker, limiting available soil moisture and affecting plant growth negatively. Seasonal rainfall is expected to decrease, with late onset of the season, season shortening and higher frequency of extremes such as prolonged dry spells, droughts, floods and intense rainstorms. A higher prevalence of diseases, due to variations in climatic conditions, has potential to adversely affect crops and livestock. There is also evidence that semi-arid conditions are expanding in the country. This will increase vulnerability to climate risk, resulting in food insecurity.

Despite the availability of the National Climate Policy (2017), National Climate Change Response Strategy (2014), and climate smart agriculture manuals and framework, an understanding of current and potential vulnerabilities and adaptation options at national and sub-national levels remains limited. Agricultural, food security and climate policies and practices are often designed at the national level with limited vulnerability assessments that capture specificity in local contexts and the projections of future conditions.

Forward-looking research is required, which forms the basis for improved understanding and determination of climate risks and adaptation options for informed action. However, to generate research results and products is not enough. Currently, a lot of research is being conducted, with limited influence on policy-making and action. This necessitates policy review to facilitate the uptake of the research products and strengthen relevant data collection for continued research-informed decision processes.

There remains a need to build human and institutional capacity at national and sub-national levels to help plan, guide and apply research to inform climate change adaptation decisions. This is to support the generation of relevant information, making use of climate projections and guiding technical extension and climate services. Feedback from applications by farmers is critical for tailored adaptation interventions.

Results from AgMIP CLARE

1. There is need for research-based climate planning and action

Researchers and experts in Zimbabwe identified the integration of forward-looking research in policy processes as critical. This integration enables climate planning and action.

Multiple ways were identified through which research can enhance climate change adaptation planning and action in support of national and sub-national goals and processes.

Plausible agricultural development pathways: Improving forward-looking research methods for analyzing impacts of climate change and performance of specific agricultural systems under future conditions involves identifying key drivers of change to influence policy making as conditions change. Differentiating particular farming systems, distributional impacts on farm types and communities, and considering whole-farm decisions is critical to ensureing that national policies meet local needs.

Consistency in policy and decision-making: There is need for increased efforts in widening the evidence base for adaptation in agricultural decision-making.

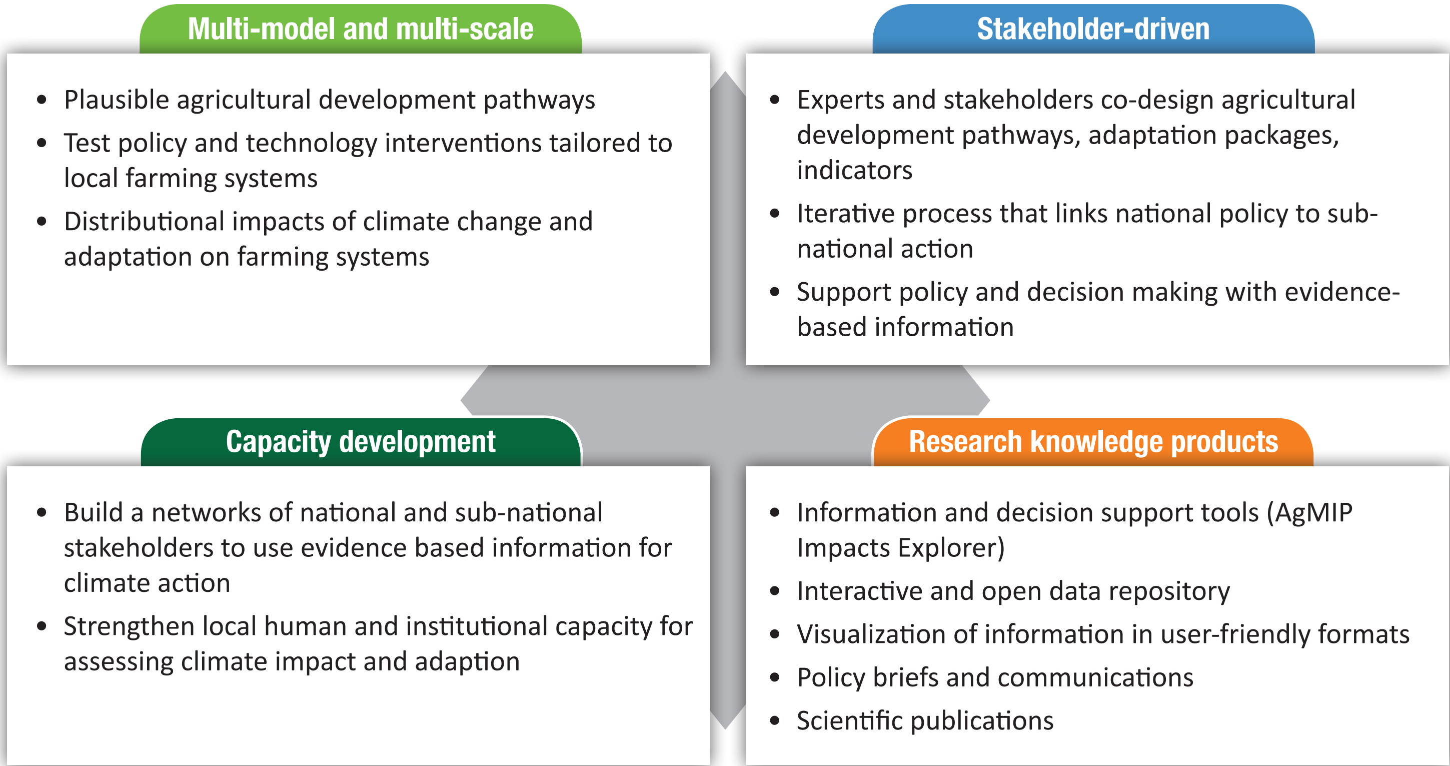

Figure 1. AgMIP research tools and data to support climate adaptation decision-making.

Comparative analyses of different farming systems, vulnerability and impact of adaptation interventions could inform and subsequently improve policy coherence, planning, coordination and sustainability of actions.

Integrated agricultural initiatives: There is need to build a collaborative environment that takes advantage of and engages with agricultural research and development investments and platforms in order to consult different perspectives and to inform and increase adaptive capacity through policy processes. These can include Livelihoods and Food Security Programme (LFSP), Zimbabwe Agriculture Growth Programme (ZAGP), Zimbabwe Agriculture Knowledge and Innovation Services (ZAKIS), and Zimbabwe Resilience Building Fund (ZRBF) programme.

New initiatives such as forecast-based financing and macro-insurance should tap into research generated by AgMIP CLARE to guide impactful actions and increase farmers' resilience against possible climate and other shocks.

Strengthening national climate policy frameworks: Research projects such as AgMIP CLARE could participate in and contribute to the implementation of national programs such as National Climate Policy (NCP), National Climate Change Response Strategy (NCCRS), Climate Smart Agriculture (CSA) Framework and Green Climate Fund (GCF) country programme. This can feed into the ongoing National Adaptation Programme (NAP) processes and climate research programs through anticipatory planning and action.

Synergies across sectors: Misalignment between sectors, stakeholders and policymaking tends to be compounded by limited collaboration between public and private sectors in terms of the research that they are conducting. There is need for collaborative research to develop and evaluate adaptation technologies within the agriculture sector and this should also feed into policy formulation processes.

Technical capacity: A program is needed to strengthen national forward-looking research capacities on new climate and integrated farming systems simulation methods. There is also need to build expert, stakeholder and decision-maker capacity through more inclusive and equitable science partnerships that effectively link science to decision-making.

Science partnerships: Systematically involving experts, stakeholders and decision-makers in research planning, identifying research questions, design, implementation and interpretation of results helps produce research that is useful and can enable policy leveraging the above.

Research is therefore central for determining possible future pathways and adaptation to future climate conditions for agriculture.

Research-informed policy and decision-making for climate adaptation in Zimbabwe

"The AgMIP tool has offered important insights on future climate scenarios. For me, the next steps will include on-the-ground assessment on farmers adopting the adaptation packages and how current policy frameworks are helping farmers adapt."

Mr Busani Bafana, *a Journalist and Communication Specialist In Bulawayo, Zimbabwe*

Science communication
Foster collaborations, link to application, involve stakeholders in research planning, execution and interpretation of results

Universities
Multiply knowledge, aid capacity development of scientists, policymakers and practitioners

CCMD
Feed science-based adaptation approaches into NAP and NDC processes

"Forward-looking approaches in terms of climate simulations and integrated modeling have enormous potential. We have introduced this subject in our curriculum to capacitate students that enroll with us."

Dr Thulani Dube
Social Scientist, Lupane State University

"The AgMIP CLARE work complements the CCMD mandate on climate change assessments and planning for adaptation and mitigation actions with a focus on local-level interventions supported by national policies."

Mr Washington Zhakata and Mr Kudzai F Ndidzano
Director and Deputy Director, CCMD

Researchers — **Consultative process** — **Policymakers**

Practitioners

Science-based approaches

Research is central for determining possible future pathways, and adaptation to future climate conditions for agriculture

- Co-develop plausible agricultural development pathways for climate adaptation
- Identify key drivers of change to influence policy
- Comparative analysis widens evidence base for policy decision-making and sustainable actions
- Strengthen national climate policy frameworks
- Build capacity of experts, stakeholders and decision-makers

Address identified gaps

Draw/revise climate adaptation plan

- **Co-develop** priority research agenda
- **Improve** access to climate and socio-economic data
- **Create** platforms to share research findings
- **Capacitate** researchers and policymakers
- **Share** successes and information on all channels
- **Disseminate** key research outputs
- **Invest** in local-level climate research
- **Engage** stakeholders to validate tools and key results to support the NAP processes
- **Mainstream** research, allot budgets for collaborative climate research

Implement plan → **Monitor & evaluate**

Guiding propositions

For science to contribute to national climate change adaptation Zimbabwe can build on existing opportunities

Investment in climate research capacity can make use of and strengthen existing programs:

- NAP processes and training programs for provincial staff and stakeholders.
- Collaboration with government institutions like AGRITEX, MSD, ZINWA.
- Link these with national-level research (DRSS), universities, and development agencies.

Forward-looking research
Analyze climate projections, farming systems specific vulnerabilities and adaption impacts

Research stations
Climate-proof agricultural technologies, through demonstrations and feedback with extension services and development agencies

"This methodology is transformative in that it gives scientists, policymakers and practitioners an understanding of the likely climate direction or the convergence or divergence of models when it comes to the future scenarios. It enables researchers to understand the certainties around climate modelling or the confidence in the projections."

Dr Elisha N Moyo, *Climate Scientist, CCMD*

"There is a growing demand for AgMIP CLARE integrated assessments and collaborative research tools … They can test the impacts of adaptation packages under specified farming systems and climatic conditions. This can support mainstreaming climate change adaptation through better tailored technology packages."

Mr Gevious Sisito, *Principal Research Officer, Matopos Research Institute*

NAP - National Adaptation Plan; **AGRITEX** - Agricultural Extension Services; **MSD** - Meteorological Service Department; **ZINWA** - Zimbabwe National Water Authority; **DRSS** - Department of Research and Support Services, **CCMD** - Climate Change Management Department

2. Bridging research-policy gaps

For science to contribute to Zimbabwe's national climate change adaptation decision processes using coherent approaches to sustainable agricultural development, the country must make use of its strengths and build on existing opportunities. Table 1 outlines the specific strengths, opportunities, weaknesses and constraints as they relate to science policy collaboration and the strengthening of climate change adaptation in agriculture.

3. Going into action

Stakeholders provide guiding propositions for developing climate adaptation planning using science-based approaches that address identified gaps by:

1. Developing a priority research agenda for climate change adaptation planning based on cross-sectoral consultative processes through higher level coordination mechanisms such as the Research Council of Zimbabwe (RCZ).
2. Improving access to climate and socio-economic data such as climate and weather data, production, income, commodity and expenditure survey (PICES) made available as public goods for assessments and to contribute to national processes through the respective Ministries.
3. Establishing and supporting platforms for interaction between policymakers, scientists and practitioners to share recent research findings through conferences and symposiums, research and demonstration tours.
4. Capacitating and motivating researchers on the writing of policy relevant communications such as policy briefs and communications. This facilitates public acknowledgements of research contributions.
5. Making policy relevant research information and success stories available and accessible via platforms, networks, databases and online media through mandatory instruments.
6. Sustaining and disseminating key outputs from research projects that influence policymaking to support adaptation planning and implementation. Deliberate efforts have to be made to involve key actors and organizations such as Ministry of Agriculture, Meteorological Service Department (MSD), Zimbabwe Vulnerability Assessment Council (ZimVAC), United Nations (UN) Agencies, National Rainfall Forecast for Zimbabwe and Southern Africa Regional Climate Outlook Forum.
7. Investing in climate research capacity to make use of and strengthen existing local level research programs,

Table 1. Strength, Weaknesses, Opportunities, Constraints (SWOC) analyses for science-policy collaboration for climate change adaptation in agriculture by experts and stakeholders in Zimbabwe

Strength	Weakness
• Institutional structures exist that can be revitalized/strengthened to take up research, e.g. Department of Research and Support Services (DRSS), Agricultural Research Council of Zimbabwe (ARC), Research Council Zimbabwe (RCZ), Zimbabwe Economic Policy Analysis And Research Unit (ZEPARU), research and academic institutions. • Existence of inclusive engagement platforms and processes, e.g. National climate change institutional framework, Green Climate Fund (GCF) country programme, agricultural working groups. • Existence of policy and legislative frameworks, e.g. Research Council of Zimbabwe (RCZ), Scientific and Industrial Research and Development Centre (SIRDC) • Education 5.0, promoting research-based innovation	• Limited interface to use research evidence in policy processes • Research messages not responsive to policy needs and not adequate to inform policy processes and implementation • Limited coordination and working in silos among government entities, development agencies and research • Capacity gaps in climate related research
Opportunities	**Constraints**
• Models that reflect processes and realities, scalable decision support • Political willingness and research oriented decision-makers including ministers • Research to determine impacts of policies supporting investments and visualize returns on those investments • New research approaches that can create better evidence base for funding adaptation action • National and international networks for research policy integration, e.g. AgMIP, Regional Universities Forum for Capacity Building in Agriculture (RUFORUM)	• Limited knowledge-sharing platforms • Limited resources and competition • Limited policy monitoring and accountability systems • Inadequate human capacity and development thrust • Fragmented structures and processes • New threats like Covid-19

e.g. National Adaptation Plan (NAP) training programs for provincial staff and stakeholders. This should enable collaboration with other institutions like MSD, Zimbabwe National Water Authority (ZINWA), and link those with national-level research and development agencies.

8. Strengthening NAP process with evidence-based data and information on how adaptation policies, technologies and strategies may impact smallholder farmers. Engage stakeholders to demonstrate the tools and key results to support the NAP development process.
9. Mainstreaming research through appropriate budgetary allocations. These should support collaborative climate relevant research proposal development to support Zimbabwe's commitments, e.g. the NAP and Nationally Determined Contributions (NDC) processes, in response to identified gaps.

Conclusion

Climate change worsens poverty for large parts of the population in Zimbabwe. There are multiple efforts to incorporate climate change adaptation in agricultural programs. However, there are gaps between research and policy that limit context-specific and effective responses to climate change through relevant mitigation and adaptation interventions. Resolving the disconnect between research processes and policy making through evidence-based decisions will support the contribution of climate action to agricultural transformation. Forward-looking research and the improvement of researchers' and stakeholders' capacity can be used more effectively to enhance policy coordination and the mainstreaming of climate change adaptation in agriculture. The process of improving research policy linkages and capacity development can contribute to processes that support access to climate finance for local action. This would strengthen Zimbabwe's approach towards meeting the national vision 2030, Sustainable Development Goal (SDG) targets, and climate change commitments under the Paris agreement.


Photo: Patricia Masikati, ICRISAT

Mucuna, a high protein, drought-tolerant legume not only improves soil fertility and resists Striga, but also helps smallholder crop-livestock farmers cope with climate change.

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Acronyms

AgMIP	Agricultural Model Intercomparison and Improvement Project
ARC	Agricultural Research Council of Zimbabwe
CLARE	AgMIP, Climate Change Adaptation and Resilience
CSA	Climate Smart Agriculture
DRSS	Department of Research and Support Services
GCF	Green Climate Fund
LSFP	Livelihoods and Food Security Programme
MSD	Meteorological Service Department
NACOF	National Rainfall Forecast for Zimbabwe
NAP	National Adaptation Plan
PICES	Production, Income, Commodity, Expenditure Survey
SARCOF	Southern Africa Regional Climate Outlook Forum
NCP	National Climate Policy
NCRS	National Climate Change Response Strategy
RCZ	Research Council Zimbabwe
ZAGP	Zimbabwe Agricultural Growth Programme
ZAKIS	Zimbabwe Agricultural Knowledge and Innovation Services Project
ZEPARU	Zimbabwe Economic Policy Analysis and

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ICRISAT International Crops Research Institute for the Semi-Arid Tropics

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Climate change and adaptation impacts in mixed crop-livestock systems in south west Zimbabwe

Policy Brief 39
November 2021

Drought and disease tolerant fodder legume mucuna pruriens enriches the soil in nitrogen and provides valuable protein-rich fodder resources for the farmer.

AgMIP projections show that poverty will reduce significantly if climate smart technologies are adopted. Yet many, especially those without livestock, will remain poor.

Key messages

1. Science-based evidence should play a key role for guiding Zimbabwe's national agricultural and climate change related policies and adaptation options.
2. In south west Zimbabwe where soil fertility is low, crop and livestock productivity, poverty, and food insecurity can only be reduced with transformation of the agri-food system.
3. A sustainable agricultural development pathway (SD) that diversifies crop production and enhances the livestock sector may provide effective and equitable solutions, enabling farmers to increase farm incomes and food security in a future that includes climate change.
4. Raising the economic importance of livestock involves increasing livestock offtake levels and milk production through better integration with crops, and ensuring that the resource poor participate in and benefit from interventions and improved markets.
5. Vulnerability to climate change is high with increased productivity, as the risk to lose also increases. Investment in SD offsets the negative impacts of climate change more effectively. Climate change adaptation strategies are thus needed to support the transformation of agri-food systems while minimizing risk of losses.
6. Improved livestock feeding (crop residues, forage, supplements) and switching from cattle to goats are some of the profitable ways to adapt to climate change, which increases the likely return on farm system improvement as well.
7. However, in order to address inherent trade -offs with environmental benefits and reducing GHG emissions, more drastic mitigation efforts are required. Improved feed production and livestock feed conversion are critical to enhance individual animal productivity and resource use efficiency.

About AgMIP CLARE

Given the need for more effort to enhance climate action, the AgMIP (Agricultural Model Intercomparison and Improvement Project) CLARE (Climate Change Adaptation and Resilience) project provides tools, and information to better understand vulnerabilities of agriculture to climate change, and its performance under plausible future pathways, towards enhanced climate change adaptation and resilience. The collaboration with multi-scale and multidisciplinary experts and stakeholders to undertake and validate forward-looking research is set to guide actionable agriculture and climate change policy decisions.

ICRISAT INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS

AgMIP The Agricultural Model Intercomparison and Improvement Project

Introduction

There is increased urgency in Zimbabwe toward climate change adaptation planning in agriculture, and towards building a shared national vision for agriculture and food systems transformation. However, there remain knowledge gaps in national level climate change adaptation planning for agriculture, including in terms of science but also policy making, as well as how best to create linkages across scale for implementation at a sub-national level.

The particular conditions of agricultural systems in semi-arid areas are not adequately addressed by agricultural and climate change related policies, strategies and action plans to allow for meaningful participation by this community in the country's vision 2030 and business paradigm shift. Challenges to adaptation in high risk areas, including in the southwest of Zimbabwe, are not yet sufficiently captured, so do not adequately inform planning and decision making at national level. Without scientific evidence and bottom-up interaction, national policy and practice are not sufficiently sensitized to the locally specific requirements.

Therefore, forward looking research is required to inform national agricultural and climate change adaptation policy planning through improved feedback from implementation in particular agricultural systems. This brief illustrates of what would happen in different farming systems, should the country continue along one agricultural pathway or another.

About AgMIP CLARE Regional Integrated Assessment (RIA)

The AgMIP CLARE project uses a Regional Integrated Assessment (RIA) and stakeholder engagement approach to explore impacts of climate change and adaptation decisions on particular farming systems, allowing decision-makers to identify which adaptation package would best improve outcomes under future conditions.

Key features include (Figure 1):

- **Stakeholder driven approach**: Scientists work in collaboration with experts and stakeholders throughout the research process, to characterize farming systems, set priorities, identify indicators and co-design pathways and adaptation/mitigation packages, review and validate research results and identify ways to disseminate the information to users.
- **Multi-model and multi-scale framework**: Multiple climate scenarios, crops and livestock economic models allow more holistic analyses, while they also provide information on uncertainty in projections. Linking sub-national farming system simulations with the national level vision for agricultural development, we can examine the extent to which national policies can be implemented at the regional scale.

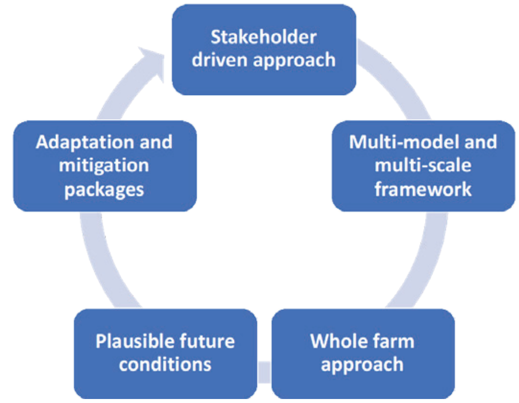


Figure 1. Key features of the AgMIP CLARE approach, part of an iterative science policy engagement approach.

- **Whole farm approach**: A range of economic, food security and emission indicators can be projected by capturing the important household, on-farm and off-farm activities and characteristics, including biophysical conditions like soil fertility, crop and livestock management, crop production, herd sizes and off-takes, cultivated land, herd, and farm size. The distribution of likely impacts of climate change and adaptation uptake can be projected for particular farming communities and households.
- **Plausible future conditions**: Representative Agricultural Pathways (RAPs) are co-developed in an iterative process with experts and stakeholders. Sub-national RAPs characterize future plausible socio-economic and biophysical conditions under which climate change might impact future agriculture. National RAPs capture agricultural development policies and climate specific policies of the agricultural sector (e.g. vision 2030 for sustainable development).
- **Adaptation and mitigation packages**: Climate change adaptation options are co-designed in a way that captures local context and suitable for specific farming systems. They incorporate economic aspects, policy interventions, improvements of infrastructure and markets in response to climate change. Trade-offs with mitigation options are being considered.

Unpacking impacts of climate change

AgMIP CLARE aims at better understanding the impacts of climate change to devise climate change adaptation and mitigation strategies. We chose a typical mixed crop livestock agricultural system, here in the case of Nkayi District in agro-ecological zone IV. First, we looked at current agricultural systems in Nkayi District, with extremely low agricultural productivity. Then, we developed different agricultural pathways to characterize future conditions and to understand what needs to be improved for agricultural development and climate change adaptation that could guide Zimbabwe towards meeting the goals of its agricultural vision 2030, and its commitments towards the Sustainable Development Goals.

We investigate the range of climate and adaptation impacts for hotter and wetter conditions as well as hotter and drier conditions, the latter of which is considered the most likely. Impacts were analyzed for the three types of farm households found in Nkayi District. 42% of households are without cattle and termed *'extremely resource poor'*; 36% of households have with 1-8 cattle and are termed *'resource poor'*, and 12% of households have 8 or more cattle and termed *'non-resource poor'*.

Current agricultural systems and impacts of climate change

Current national policies

Current polices and socio-economic conditions influence the extent of the impacts of climate change in Zimbabwe and guide the response interventions. Zimbabwe aims to transform its agricultural sector, towards enhancing agriculture's contribution to the national GDP, and combatting the impacts of climate change, reducing its devastating impacts on poverty and malnutrition. The National Development Strategy 1 (NDS1) prioritizes commercializing the agricultural sector and building resilience to climatic shocks, while stabilizing the macro-economic environment. The Agriculture and Food Systems Transformation Strategy targets 7.8% annual growth rates by 2025, with efforts to climate proof the agricultural sector. The Food and Nutrition Security Policy (FNSP) exhibits the commitment to reduce poverty, food and nutrition insecurity. The National Climate Policy (NCP) is being mainstreamed across all sectors through multi-stakeholder approaches.

The case of Nkayi district

Agricultural activities are predominately maize production, with limited small grains and legumes. Cattle and small ruminants provide farm inputs and income. Agricultural productivity is extremely low, with most soils of poor fertility, with limited investment in livestock feed, and pest and disease pressure.

Given the already low agricultural productivity in Nkayi district, the relative magnitude of the climate change impact was small, though it did vary by farming activities and farm types.

Climate: Increasing temperatures across the season by 1 to 3ºC, along with low and erratic rainfall (<650mm annual average) and a likely decrease in rainfall by up to 23%, result in overall drier climate. Higher temperatures accelerate phenological development, shortening the time for biomass accumulation, reduced yields and changing rangeland plant diversity. Less rain implies water stress.

Crops: Crops showed a range of responses to climate change, depending on climate scenarios and soil fertility (Figure 2). Soil fertility influences crop sensitivity to climate impacts. Poor soil fertility locks farmers into a low level of crop productivity. In Nkayi, about 78% of the farmers plant maize in very poor soils, and as such, there is little response by maize to climate change in these locations. Groundnuts tend to benefit from climate change, as higher CO_2 concentrations offset the impact of increased temperature. Only the 12% *non-resource* poor farmers, on soils with better fertility, had higher crop yields. However, the impacts of climate change were also found to be larger for this group.

Livestock: Feed deficits affected the few farmers with larger cattle herd sizes more negatively. Hot dry conditions on rangelands and crop residue biomass reduced feed intake of livestock, further reduced livestock productivity. Under hot wet conditions, the impacts of climate change were small.

Economic impacts: Poverty levels and food insecurity were extreme in Nkayi District. The majority of household were below the poverty line (83%) and struggling to produce maize on poor soils while keeping some livestock. Climate change worsened the conditions for these farmers, even though the impacts on poverty levels were mostly small (<5%). Farmers with larger cattle herds experienced greater economic losses due to feed shortages. They were likely to have alternative means to compensate for these losses, as compared to the poor, and were less likely to experience complete losses of assets than the poorer farms.

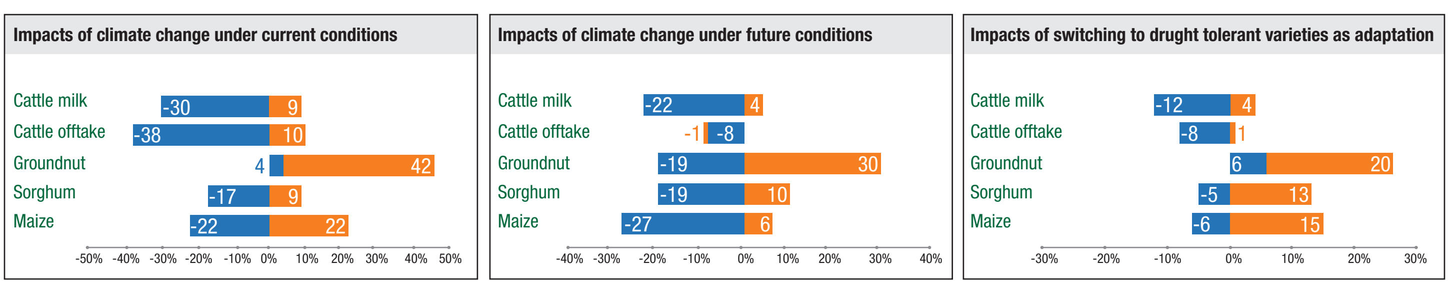


Figure 2. Relative change in yields (%) for crop and livestock outputs, Nkayi District.

Hot dry Hot wet

Vulnerability to climate change was explored using contrasting climate scenarios, and found to be high (38-72%). Up to three quarters of households lost from hotter and drier climate. Farmers with more cattle exhibited larger feed gaps and that made them more vulnerable to the adverse effects of climate change. Vulnerability under hotter and wetter climate was lower, but still affected about a third of the households.

Future impacts of climate change

National Representative Pathways

Three Representative Agricultural Pathways (RAPs) were co-designed with experts and stakeholders. One represents a Business As Usual (BAU) scenario, one Sustainable Development (SD) and one Unsustainable Development (UD).

The RAPs help to understand the behavior of agricultural systems from the current situation of extremely low agricultural productivity, alarming poverty and food insecurity moving into a future dependant on agricultural policies and other drivers that shape the conditions for responses to climate change and other shocks.

Depending on the RAP chosen, different importance was attributed to climate change adaptation and mitigation supporting agricultural development and different extent of coherence in implementation strategies (Figure 3).

Linking national policies with regional RAPs shows to what extent national policies are being implemented to improve agricultural systems in response to regional conditions (Figure 4).

The case of Nkayi district

The simulation results suggest that following the RAPs the conditions for agriculture can be improved, production increased and poverty reduced by 2030. The magnitude of impact, especially for the extremely poor, however, depends on the RAP chosen.

At higher productivity levels, the losses from climate change were higher and the magnitude of impacts was therefore larger. The RAPs differently offset the losses from climate change.

Crops: Crop productivity levels were higher in future, and the range of climate change impacts on crop productivity was large. The SD pathway increased crop yields more as compared to UD and BAU pathway through cultivation of climate-resilient high-yielding dryland legumes (groundnut and forages). Cereal yields were increased on smaller land through organic soil fertility amendment. Improving soil quality exhibited higher yields. The resource-poor benefited more from improved crop production.

Livestock: Supplementary feeding was key to reduce losses to climate change. SD raised the economic importance of livestock addressing strategic bottlenecks through the inclusion of (i) supplementary feed (crop residues, forage, supplements) to improve livestock productivity (ii) mechanized crop cultivation to release cattle from draft power (iii) improved market access to raise off-take levels. Negative effects of higher temperature and CO_2 levels on rangelands resulted in higher supplementary feeding of commercial feeds. A national restocking strategy in response to the increasing

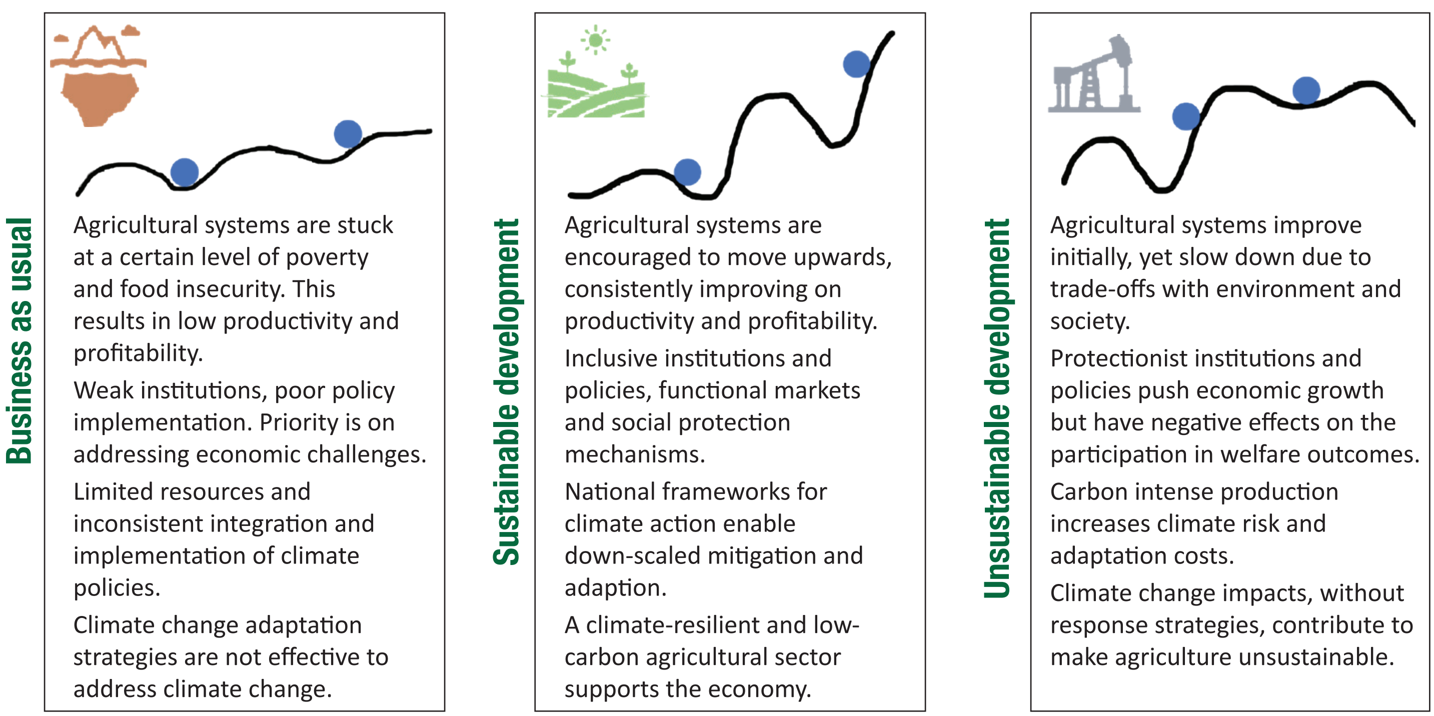


Figure 3. National Representative Agricultural Pathways (RAPs) in Zimbabwe, systems behavior, drivers and outcomes (2030).

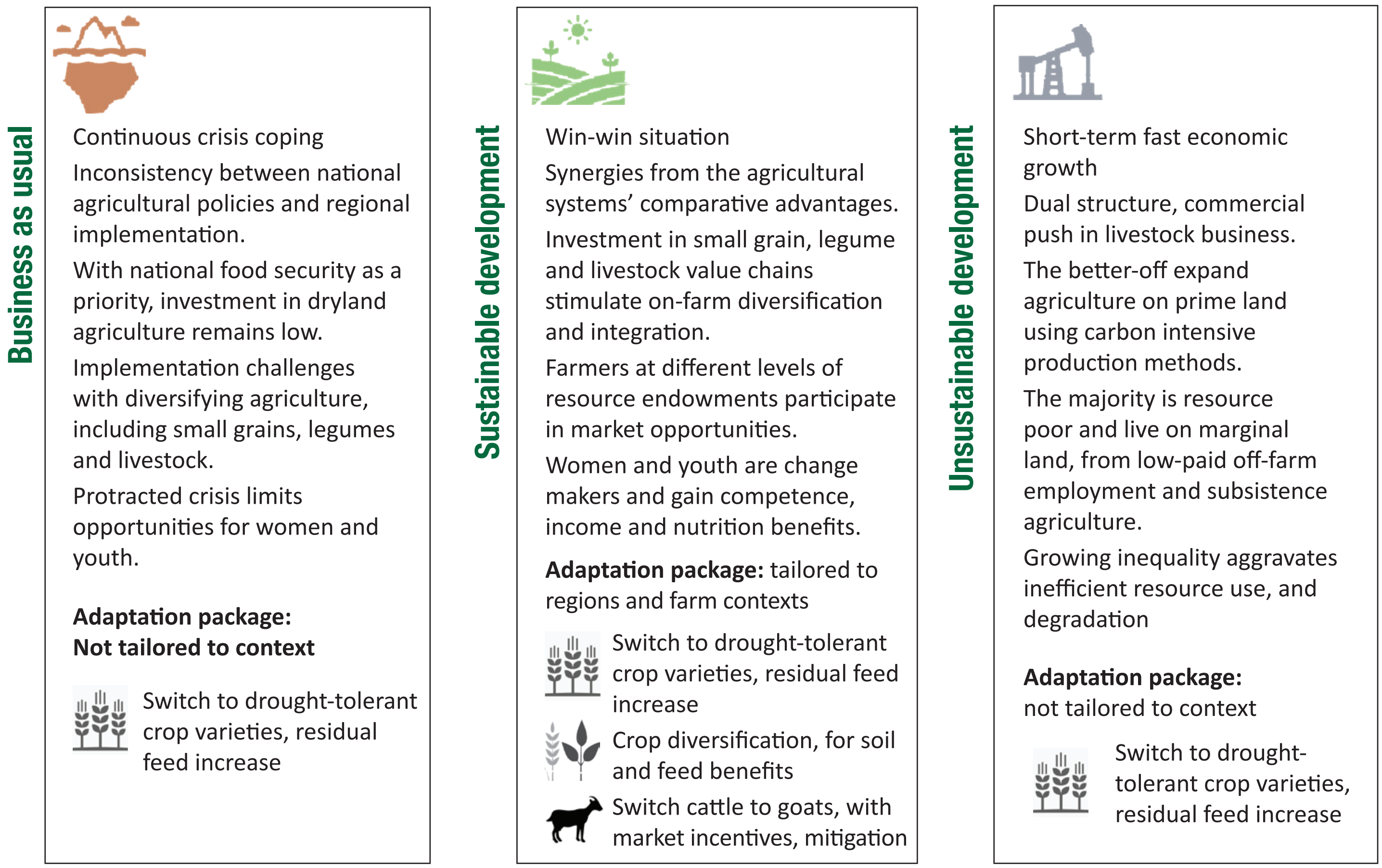


Figure 4. Regional implementation and respective adaptation packages (2030).

demand for livestock provided every household with at least five cattle. Under the UD pathway resource-poor farmers were excluded from keeping cattle.

Economic impacts: The main issue for mixed farming systems in Zimbabwe, regardless of climate change, was to look at improvements that would reduce poverty and inequality (Figure 5). Following Sustainable Development was more effective as agricultural incomes increased for all households and poverty rates reduced to 34%. Unsustainable Development and Business As Usual increased inequality, agricultural incomes improved for the better off, however, the majority of resource-poor households did not benefit from agricultural policies under these two RAPs and poverty rates remained high at 65 and 80%, respectively.

With improved economic development the impact of climate change on poverty levels was small (<5%). However, a large proportion of households was still vulnerable to climate change (47-60%). Under the SD pathway the resource poor were more vulnerable to climate change, yet higher and more profitable agricultural production offset the impacts of climate change.

Future impacts of climate change adaption in Nkayi Districts

Advising adequate climate change adaptation and mitigation strategies is critically important to ensuring that the benefits from economic investments are not lost. This needs to support reducing poverty and improving farms resilience to climate change.

The SD pathway adaptations (with 3 options) provided larger benefits to farmers, accomplishing the goals of improving farmers livelihoods and making the system more resilient to climate change, moving the system towards meeting the SDGs (Figure 6). The adaptation strategies under BAU and UD pathways provided small benefits for farmers with cattle. Those resource-poor farmers without cattle remained with very low income, which demonstrates that following those pathways would make it difficult (or worse) to improve the livelihoods for resource-poor farmers.

Adaptation package 1 (A1): Switching to drought-tolerant varieties is one important strategy to adapt to increasing temperatures. Adoption rates were between 51 and 55% across the three RAPs. The impact on farm incomes was,

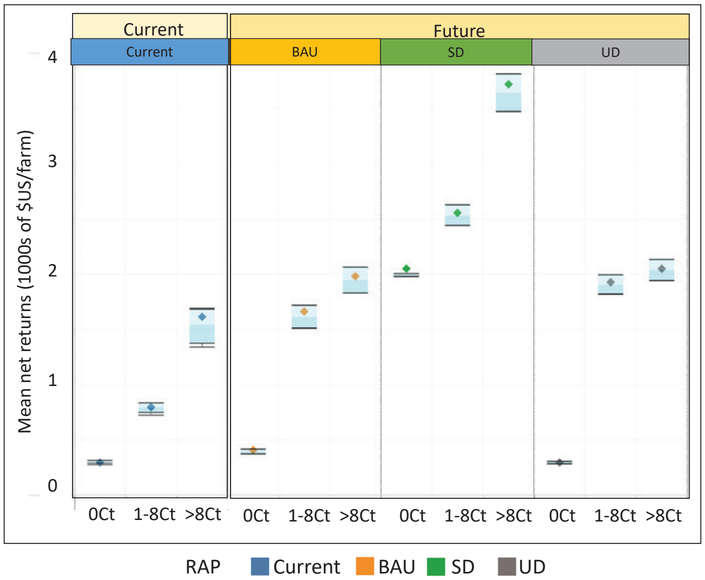
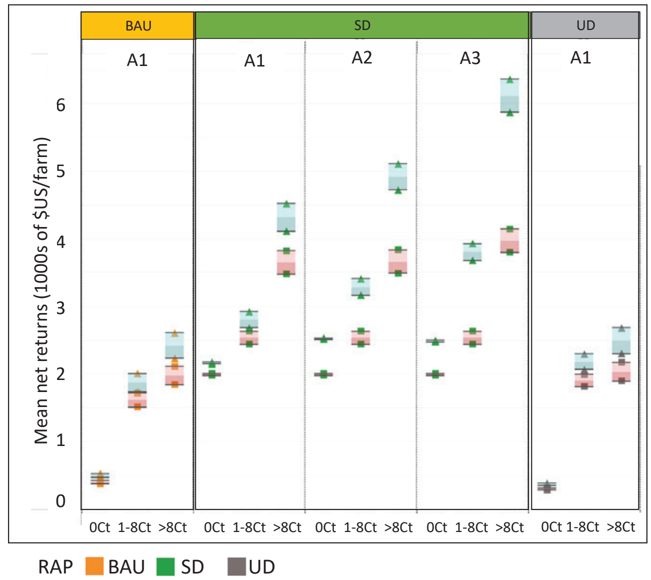


Figure 5. *Impact of agricultural development and climate change for RAPs [Business as Usual (BAU), Sustainable Development (SD) and Unsustainable Development (UD)] and climate scenarios (Hot-Dry, Hot-Wet), and farm types in Nkayi, Zimbabwe, using APSIM and DSSAT results as input.*



Pink blocks = Mean Net Returns (NR) with Climate Change (CC)
Blue blocks = NR with CC and adaptation

Figure 6. *Impact of adaptation to climate change for RAPs (BAU, SD, UD) and climate scenarios (Hot/Dry, Hot/Wet), and farm types in Nkayi, Zimbabwe, using APSIM and DSSAT results as input.*

however, relatively small with increased farm net returns of 8 to 20%. The adaptation package alone is therefore not sufficient.

Adaptation package 2 (A2): In addition to the components of A1 in this adaptation, deliberate efforts were made to further increase the feed supply for livestock, converting land into high-yielding *leucaena.* The majority of farmers (84 to 86%) adopted this package, farm incomes increased by 28 to 32%.

Adaptation package 3 (A3): In addition to the components of A2, switching from cattle to goats was tested as an adaptation strategy, as the smaller and more resilient livestock are easier to handle, especially for women. In a next step a price incentive of 15% price increase was offered to stimulate the conversion. This package was attractive for most farmers, with a projected adoption rate of 88-90%. This increased farm incomes by 41-43%. It illustrates that financing a shift from cattle to goats can provide important adaptation benefits.

Mitigation impacts: Switching cattle to goats had however limited impacts on reducing greenhouse gas emissions. Hence more drastic mitigation efforts are required in terms of feed improvement and improving individual animal productivity.

Policy recommendations/actions

Supporting agricultural transformation

Agricultural policies and future conditions in Zimbabwe will shape the structure of farming systems in the country, with varying consequences of climate change and adaptation measures under different pathways.

The country can explore contrasting agricultural pathways (RAPs) established among policy experts and AgMIP scientists in the region. Features of RAPs, designed specifically for dryland systems in Zimbabwe, illustrate that addressing poverty, food insecurity and inequality are most critical issues, which can further deteriorate under climate change. Not investing in SD can deepen poverty and food insecurity for the majority of the population and increase inequality. Given that under BAU and UD the majority of farmers still operate on soils of poor fertility, it will be more difficult to get those out of the ‘locked’ state in future. These are very strong arguments for inclusive policies, interventions and tools to support the transformation of the agri-food system.

Transforming agri-food systems in semi-arid areas starts with recognizing that climate change is not the main problem. The problem is that the majority of farmers are trapped on poor soils with low input access and use, and low levels of resource endowments. With high levels of labor migration this takes a toll, especially on women.

To reduce poverty and increase farm household food security, a shift in focus is needed from narrow or time limited food security strategies (BAU), towards pathways that enable ongoing policy-supported solutions appropriate for local condition, with a focus on improved farmer well-being (SD). Climate change adaptation and mitigation needs to support poverty reduction through measures that are well-tailored, gender sensitive and integrate farmers at varying levels of resource endowments.

This would involve:

Crop diversification: Part of transformation in technical investments is to cultivate maize on smaller land and thereby release land to increase the contribution by other crops, notably legumes and other underutilized species, with strong climate resilience and nutrition-density.

Soil fertility and health: Soils play an important role and can act as buffer to reduce impacts of climate change on crop production. Strategies that also improve the soils are important for possible future modified crop genetics for increased resilience to climate factors such as rainfall and CO_2; this is especially true for legumes, which improve soil fertility and provide nutritious food and feed for livestock.

Crop improvement: The contribution of genetic crop improvement can be more effective if combined with (i) improved soil fertility for higher yield response and (ii) market improvements as incentives for farmers to budget these varieties. Synergies with other management components are thus critical to increase the returns on crop improvement.

Market oriented investments: Enhancing market participation is critical for all farmers to increase off-take and farm reinvestment as well as to increase productivity, farm incomes and resilience. Policy support is required to enable the shift to more profitable agriculture, while reducing the risk to lose from climate change.

Social protection: Vulnerability was found to be high in future, and there were households 'locked' in poverty. Social protection mechanisms are thus critical, as are adaptation packages that minimize the likelihood of future losses from climate change, especially in resource poor households.

Adaptation strategies in response to climate change

Given the variable impact of climate change on the different farm groups, policy makers who understand the dynamics of climate change may better formulate effective climate policies for the future that consider, and address this dynamic, so as to ensure the impacts of climate change on poverty do not increase while farm groups improve their well-being.

Switch to high-yielding biomass crops pays off through improved soil fertility and livestock feed, better adapted cultivars for the poor soils typical in these areas, improved access to nutrient-dense diets, and learning about climate change factors.

Shifting from cattle to small livestock such as goats will promote the resilience of the livestock sector because small livestock demands less water and can better withstand stressful climatic conditions.

The success of adaptation packages is however not possible if there is not adequate investments in markets, infrastructure, and knowledge to enable the adaptation.

Mitigation

For drylands, integrated and diversified crop-livestock system is a recommended strategy to generate income and livelihoods. To reduce livestock greenhouse gas emissions, strategies to address co-benefits from adaptation and mitigation are important. An assessment of the trade-offs of policy and technology interventions between environmental, social and economic outcomes can inform policies that enable such strategies.

For example, the impacts of shifting cattle to goats for reducing the emission of methane, as demonstrated in the example of Nkayi District, were limited. Hence more drastic mitigation efforts are required in terms of improving local feed production and individual animal productivity. More research is needed on improving livestock feed conversion, while not losing the adaptiveness of local breeds.

Conclusions

The results of simulation assessments can guide decision processes for Zimbabwe as policy makers and scientists work together to understand the complexity of likely outcomes, as well as the consequences on policy decisions. The efforts should lessen the gap, and increase informed action and investment toward farming systems with pathways to address shortfalls beyond just climate change, that make for effective adaptation to climate change. These sorts of analyses are also important to the exploration of mitigation co-benefits that further farm household well-being while maintaining local biodiversity.

This supports coordination between national and localized adaptation and mitigation planning in agriculture, aiming at raising the food basket while mainstreaming climate change adaptation, and understanding trade-offs with mitigation. An improved understanding of the effectiveness of adaptation strategies at the local level, gaps in national policies can be identified, with regards to technical implementation and the level of granularity required.

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Accronyms

AgMIP CLARE	Agricultural Modeling Intercomparison and Improvement Project Climate and Resilience
BAU	Business as Usual RAP
RAP	Representative Agricultural Pathway
SD	Sustainable Development RAP
UD	Unsustainable Development RAP

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AgMIP Adaptation Teams Start-Up – A CLARE Transition Activity

Supporting national climate change planning for agriculture in Ghana, Senegal and Zimbabwe: A report from baseline stakeholder interviews and surveys

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A Mid-Project Technical Report of the CLARE Program

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List of Abbreviations and Acronyms

AgMIP	Agricultural Model Intercomparison and Improvement Project
AGRITEX	Department of Agricultural, Technical and Extension Services
ANACIM	National Agency for Civil Aviation and Meteorology
ANCAR	National Agency for Agricultural and Rural Advice
CCAFS	Climate Change, Agriculture and Food Security
CCASA	Adaptation of Agriculture and Food Security to Climate Change
CCWG	Climate Change Working Group
CERAAS	Centre d'Etude Régional pour l'Amélioration de l'Adaptation à la Sécheresse, (Regional Study Center for Improving Drought Adaptation)
CESE	The Economic, Social and Environmental Council
CNIA	National Interprofessional Peanut Committee
CNCR	National Council for Consultation and Cooperation for Rural People
COMESA	Common Market for Eastern and Southern Africa
COMNACC	National Committee to Combat Climate Change
COMRECCs	Regional Climate Change Committees
COP	Conference of Parties
CSA	Climate Smart Agriculture
CSE	Centre de Suivi Écologique
CSOs	Civil Society Organizations
DA	Directorate of Agriculture
DAPSA	Senegalese Directorate of Analysis, Forecasting and Agricultural Statistics
DFC	Decentralizing Climate Funds
DP	Development Partners
EMA	Environmental Management Agency
EPA	Environmental Protection Agency
FAO	Food and Agriculture Organization
FDI	Foreign Direct Investment
GEF-NAPP	Global Environment Facility - National Adaptation Programme of Action to Climate Change
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
IED	Innovation Environnement Dévéloppement
INDC	Intended Nationally Determined Contributions
ISRA	Senegalese Agricultural Research Institute
MESTI	Ministry of Environment, Science, Technology and Innovation

MLAWCRR	Ministry of Lands, Agriculture, Water, Climate and Rural Resettlement
MoFA	Ministry of Food and Agriculture
NAPA	National Adaptation Programs of Action
NAPs	National Adaptation Plans
NCCRS	National Climate Change Response Strategy (Zimbabwe)
NCP	National Climate Policy (Zimbabwe)
NDCs	Nationally Determined Contributions
NDPC	National Development Planning Commission
NEPAD	New Partnership for Africa's Development
NGOs	Non-government organizations
PAS-PNA	Scientific Support Project for the National Adaptation Plan
PNASIAN	National Agricultural Investment Program for Food and Nutrition Security
PRACAS	Program of Acceleration of the Production Rate in Senegalese Agriculture
PREFERLO	Project to strengthen the resilience of Ferlo ecosystems
PSE	Plan for an Emerging Senegal
PWG	Pluri-disciplinary working group
REPES	The Network of Parliamentarians for Environmental Protection
RNA	Assisted Natural Regeneration
SAGA	Strengthening Agricultural Adaptation
SECNSA	Executive Secretariat of the National Council for Food Security
SRI	Intensive Rice Farming System
UG	University of Ghana
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
WIAD	Women in Agricultural Development
ZimVAC	Zimbabwe Vulnerability Assessment Committee
ZINWA	Zimbabwe National Water Authority
ZRBF	Zimbabwe Resilience Building Fund
ZUNDAF	Zimbabwe United Nations Development Assistance Framework

Executive summary

The global food system faces a combination of challenges and opportunities as a result of climate change that require transformation. One of those transformations is adaptation to climate variability and change in agriculture. National climate change planning and action processes for agriculture are at the center of global efforts to improve food security, and are critical for reducing poverty and improving livelihoods in developing countries. This report documents progress, challenges, and opportunities in national climate change and adaptation planning processes in three countries in Africa: Ghana, Senegal, and Zimbabwe.

The report is based on work carried out under the Agricultural Model Intercomparison and Improvement Project (AgMIP) Adaptation Teams Start-Up – A CLARE Transition Activity (A-teams). The project engages local teams of AgMIP researchers in the selected study countries. The teams, like many other AgMIP contributors around the world, are helping to improve the use of models for understanding vulnerabilities of agriculture to climate variability and change. It uses models to consider adaptation options, collaborating with stakeholders in each country to provide information that can guide decisions. This research augments prior research AgMIP has conducted to understand in-depth likely future climate, vulnerabilities, and adaptation options in the agricultural sector in one district in each country. Each of the districts represented one of the countries' predominant farming systems. The A-teams project collaborates with stakeholders in the study countries to develop information that can guide climate change decisions in the agricultural sector at the national level.

The purpose of the reported study is twofold. First, the data and information comprise a baseline for an evaluation, which is seeking to understand if and how the science that the A-teams project develops contributes to national planning processes. Second, the findings guide the research process and the engagement with stakeholders in the A-teams project and future AgMIP initiatives.

The findings in this report are based on three sources of information.

i. Ten interviews carried out by the research teams in each country with stakeholders who participate in the national planning processes for climate change in agriculture.
ii. Surveys of a broader set of stakeholders in agriculture in each country.
iii. Review of national planning and policy documents carried out by the research teams in each country.

Summary of achievements and challenges in national planning processes

The national climate change planning processes are relatively new in each of the study countries, having begun in Senegal about 14 years ago, about 7 years ago in Ghana, and 6 years ago in Zimbabwe. While the interview respondents in each country stress that the climate change planning processes are in early stages and challenges remain, important progress has also been made.

Awareness of climate change and vulnerabilities of the agricultural sector to climate variability and change has increased in all three countries in recent years, especially at the national level. Agriculture is a high priority sector in climate change planning. Each country has an institutionalized, consultative planning process, in which a national government ministry has the mandate to set priorities, guide, develop, and approve planning processes, policies, and strategic documents. The commitment to climate change planning and endorsement for climate change and adaptation projects in agriculture from national ministries have increased. At the same time, respondents report that the commitment and endorsement are not yet sufficient. Understanding of vulnerabilities and adaptation options is still limited, and this understanding and even awareness of climate change are low at the local level.

Each country has developed a number of climate change and adaptation planning frameworks, including ones that address action in the agricultural sector in particular, for example advancing Climate Smart Agriculture. The policy and strategic documents are important not only because they set out national priorities, helping to guide planning and implementation, but also because the process of developing the documents creates a constituency that becomes influential in continuing to advance planning, implementation, periodic review and continuous improvement. Stakeholders from national and local government, research, civil society organizations, development partners, and UN and international organizations have come together to form coalitions and platforms that have contributed to the planning documents and these new networks continue to advance progress, which include policy, legal and institutional structural reviews and establishment. The documents continue to draw the attention of international development and technical partners, who are contributing expertise and funding. The processes of developing the documents have required research, which has improved the understanding of vulnerabilities and adaptation and informed action beyond the documents themselves.

The creation of partnerships, collaborations, and coalitions has been an important success of the planning processes. These bring expertise from different technical areas and levels of society into the planning and implementation process. They help participants influence the planning and implementation processes through many different channels represented by other members of the partnerships and coalitions. They share information. In particular, they inform participants about projects and initiatives related to climate change, potentially helping to coordinate efforts. Coordination is important in order to use scarce resources efficiently. Interview respondents emphasize that more collaboration and coordination is still needed. Climate change action in each country still suffers from projects that undertake the same efforts without being aware of each other, thereby missing opportunities for increasing scale, and fail to build on lessons learned. Competition over roles and mandates sometimes impedes progress.

All three countries have established relationships with international development and technical partners, and have made progress in attracting funding for climate change work. However, capacity to effectively utilize available funding and technical capacity to develop bankable projects with a strong climate rationale continues to be a significant constraint. Interviewees report limited capacity to write proposals that attract funding.

Major obstacles to progress are formulation of national policy that does not adequately reflect differences in challenges and conditions across the country, insufficient communication between local and national levels, as well as inadequate knowledge and capacity at local level to engage in climate change planning, to influence planning at the national level, and to implement adaptation strategies. Study respondents emphasize that many decisions about managing climate change and implementing adaptations are made at the local level, by local government, civil society organizations, farmers, processors, distributors, and households. The problems that decision makers face at the local level is that local experiences and solutions rarely filter into national policy-making, and without this bottom-up interaction, national policy and practice is not adequately sensitive to local circumstances and context. Approaches to adaptation that do not incorporate technologies developed at the local level may not be accepted.

Research has contributed to the successes in climate change planning and action in the three study countries. Research has developed the climate projections and understanding of vulnerabilities that have focused attention and generated commitment to action on climate change. It has informed the national documents. Research organizations have joined partnerships and coalitions and exercise influence through their technical expertise. Research is also key to funding. For example, the Green Climate Fund, which is a major source of funding for work on climate change and adaptation, requires that proposals show that the problems being addressed are caused by climate change whose impacts may remain problematic in the future based on climate scenarios and projected impacts. More generally, proposals are more likely to be successful when they are based on credible evidence.

Study respondents in each of the countries report that substantial research has been carried out on vulnerabilities and adaptation to climate change. However, much remains to be done. Information that is tailored to decisions about climate risk management and adaptation remains insufficient, as we discuss further below. Interviewees note that challenges to advancing research include availability of good quality, complete data on climate, agricultural production, and socio-economic outcomes that are critical for research. Furthermore, skilled personnel who are knowledgeable about climate change and adaptation are in short supply.

How research can contribute to building capacity

Research produces the knowledge on which the countries can base their climate action plans and programs. Adaptation efforts are not likely to be effective without a thorough understanding of vulnerabilities and what approaches to adaptation work under different conditions. However, research can contribute to advancing adaptation only if it informs decisions, which requires science that addresses decision problems in their contexts and that stakeholders trust and understand. Useful science requires engagement with stakeholders that identifies decision problems and builds the stakeholders' capacity to guide the research and to understand the research methods and results.

Research

Many interviewees mention that information needed to guide risk management and adaptation decisions in specific contexts in the countries is scarce. Information is typically aggregated at a global level or for supra-national regions. Climatology, climate projections, vulnerabilities, and adaptation options at aggregated levels may not be appropriate for guiding decisions that are made primarily at local levels given that adaptation is area-specific. Interviewees who are familiar with prior phases of AgMIP note that the information that AgMIP produced for specific districts in each country is very helpful for making decisions in those districts. The challenge is to characterize how vulnerabilities and effective approaches to adaptation differ under different climate, environmental, socio-economic, and governance conditions.

A parallel challenge is to improve understanding of how information about vulnerabilities and effective adaptations that accurately reflects different conditions in the country can inform national policy. Designing policies that successfully support approaches that are tailored to local conditions requires further research.

The interviewees mention the need for understanding benefits and costs of adaptation strategies for different populations under different conditions. Determining effectiveness of adaptation strategies requires empirical research across a range of local conditions to identify how approaches should differ across contexts. Decision makers also need more studies that combine assessments of effectiveness with costs of adaptation to guide investment in adaptation strategies under different conditions.

Research needed to develop climate information services that can guide decisions, especially farmers' decisions, emerges in many interviews, particularly in Senegal and Ghana. The research gap includes high-quality seasonal predictions, but extends beyond the skill of predictions to the prediction and communication of variables that farmers want to know when making decisions on the farm, and connecting information about climate variables to decisions. Farmers need training in how to use climate information to make informed crop management decisions in different farming systems. Research should investigate how to sustainably institutionalize the development and communication of useful climate information and capacity building to use the information among farmers on a large scale.

Another potential research area is in communicating information tailored to different types of decision makers. Despite much attention to this topic, interviewees clearly convey that information is rarely designed to be usable by decision makers, and the gap is especially wide for decision makers at the local level. The problems concern such dimensions of information as clarity of implications for decisions, clarity of scope of relevance, level of technicality, complexity, length, and language used.

Insufficient and poor-quality data are a significant obstacle to more useful research outputs. Building capacity to collect, store, manage, and disseminate complete, high-quality climate, environmental, crop, and socio-economic data at high spatial and temporal resolutions is essential for supporting useful research.

Respondents express the need for a clearinghouse of country-specific information on climate vulnerabilities and adaptation in each country. Interviewees note that information is dispersed, can be difficult to find, is not necessarily accessible, and it is difficult to gauge its credibility. The more credible the information provider, the more likely the information is to be too aggregated for use in decision making.

Engagement
The information that AgMIP has produced in past phases has not been applied to decision making widely. Much of the information remains in the research realm, and decision and policy makers are not widely aware of it.

Interviewees uniformly stress the importance of engaging with a broad set of stakeholders who work on climate change and adaptation issues in agriculture at the very beginning of the research and keeping them involved throughout the process. Early engagement should allow for stakeholders to define the research priorities and to shape how the research is done. Informing stakeholders about what has been developed at the end of the research is not likely to result in information being used. Researchers may wish to participate in meetings and workshops that occur as part of the national planning processes to hear what is being discussed, ask questions about what the stakeholders are interested in, what they do and do not understand, and in what form results may be useful.

A principal component needed in the engagement process is to build capacity among different types of stakeholders to guide the research, to understand the research methods and results, and to understand how to use the results. The types of capacities needed and the approach to improving them is likely to differ for different types of stakeholders, such as national decision makers, local government staff, civic society organizations, and farmers.

Information from interviews suggests that researchers should engage directly with national ministries that lead the planning processes in each country. Use of knowledge produced by a research project may be more likely if the ministries consider the project to be a trusted partner. Furthermore, such engagement can help the research team to understand the ministries' priorities, which are influential in the planning process, and to address those priorities with the types of information to which the national decision makers are likely to pay attention. A likely avenue for researchers to engage with the national ministries and with other participants in the planning process is to help develop the national planning documents that are in progress.

Interviewees encourage researchers to engage not only with lead ministries but also with all participants through coalitions and platforms that have formed to work on climate change and adaptation in the countries. These bodies can help to inform research about a range of priorities and important issues that may not be on the leading ministries' radars. The coalitions multiply potential entry points for research, disseminating awareness about the research and enabling the production of research that is useful to a broad set of actors. Participation in the development of national documents is again a potentially fruitful avenue for engaging. Also, respondents emphasize the importance of communication and coordination across all projects and research teams that are addressing vulnerabilities and adaptation to climate change in agriculture.

1. Introduction

The global food system faces a combination of challenges and opportunities as a result of climate change that require transformations in food production, processing, distribution, and consumption (Willett et al 2019). On the supply side of the system, food security relies on effective adaptation to extensive current and future impacts of climate variability and change on agriculture. In developing countries, agricultural sectors also influence the demand side of the food system since they support the livelihoods of the majority of the population, and therefore determine incomes available to spend on food, as well as influence diet diversity through choice of crops (FAO 2012). Furthermore, agricultural development is essential for addressing poverty and the associated food insecurity. In 2016, about 65% of poor adults relied on agriculture for their livelihoods (Castañeda et al 2016), and growth in agriculture raises incomes among the poorest populations two to four times more effectively than does growth in other sectors (Townsend 2015). National climate change planning processes are at the center of the efforts to adapt agricultural sectors in developing countries to climate variability and change.

This report documents progress, challenges, and opportunities in national climate change planning processes for the agricultural sector in three countries in Africa: Ghana, Senegal, and Zimbabwe. In all three countries the majority of the population earn their livelihoods from agriculture, 54% in Ghana in 2013 (FAO 2015a), 70% in Senegal in 2013 (FAO 2015b), and about 70% in Zimbabwe in 2015 (FAO 2016). All three countries have begun the process of developing National Adaptation Plans (NAPs), following the process established by the Conference of Parties (COP) under the United Nations Framework Convention on Climate Change (UNFCCC) in 2010. The objective of the NAP process is to support the countries in identifying their adaptation needs and priorities and developing strategies for advancing adaptation. According to respondents to interviews in this study, the process of planning for impacts of climate change in the agricultural sector began in Senegal about 14 years ago, before the beginning of the NAP process, while it began in Ghana about 7 years ago, and 6 years ago in Zimbabwe. All three countries have reached important milestones, and significant challenges remain.

This report is based on work carried out under the Agricultural Model Intercomparison and Improvement Project (AgMIP) Adaptation Teams Start-Up – A CLARE Transition Activity (A-teams). The objective of the A-teams project is to collaborate with stakeholders in the three study countries to build capacity in the national climate change planning processes for agriculture to advance adaptation in the agricultural sector. The project is extending information developed under prior AgMIP phases for one region in each country to the national level. The information includes climate projections; assessment of climate impacts on agriculture integrating impacts on production and economic impacts (Regional Integrated Assessment); the development of pathways that production and livelihoods in the agricultural sector may follow under several climate and adaptation scenarios (Representative Agricultural Pathways); and an online, interactive repository for the information, the Impacts Explorer.

The A-teams project includes an evaluation of the contribution that science developed in the project may make to the national climate change planning processes. The evaluation will integrate quantitative and qualitative data to document change in outcomes in the planning processes over the course of the project and investigate why those changes occurred. The evaluation also serves to inform objectives and processes for future phases of AgMIP.

This report presents the findings of the first phase of the evaluation analysis, the baseline. The objectives of the baseline data collection are to: (1) Document national climate change planning processes, what information they use, and any role that past AgMIP research has played at the beginning of the CLARE project; and (2) Help inform what the CLARE project should focus on and how it may influence planning processes to advance adaptation in agriculture most effectively. Information in the report is based on data collected through (1) interviews with stakeholders who participate in the planning processes in each country, (2) a survey of a broader set of stakeholders in the agricultural sectors in the countries, and (3) documents reviewed by research teams in each country.

2. Data and methods

Sampling and data

The first source of information from which findings in this report draw are semi-structured interviews with 10 stakeholders who participate in the national climate change planning processes for agriculture in each of the three study countries. The stakeholders whom we interviewed represent a range of institutions and roles in national planning, including leading government ministries, other government ministries and departments, coalitions, development and technical partners, and researchers. The research teams in each country identified respondents for the interviews based on institutional mapping. Each team categorized the organizations that are the main players in the planning process into four categories: organizations that have strong policy influence and scientific and technical expertise, ones that have low policy influence and strong scientific and technical expertise, those that have high policy influence and low scientific and technical expertise, and those who have low policy influence and scientific and technical expertise. They selected organizations from each of these categories and one or more individuals who hold high office in each of the organizations.

Members of the research teams in each country interviewed stakeholders over the phone. We were unable to conduct interviews in person due to restrictions imposed as a result of the Covid-19 pandemic. The interviews followed a discussion guide, which contained the same questions in each country. We translated the interview guide for Senegal into French.

The second source of information is analysis of data collected through a survey of stakeholders in the agricultural sectors in the three countries. The sample for the baseline survey comes from all stakeholders in the agricultural sector, a broader set than participants in the planning processes. The sample is not random. The sample includes researchers and decision makers identified by the research teams in each country and additional individuals identified through a snowball process in interviews and other interactions with stakeholders.

We programmed the questionnaire in Survey Monkey. The respondents received a link to the survey. They filled it out on their own computers. Questions and answer options were based on information collected through interviews. The questions in the questionnaires were the same in each country. There were some differences in answer options for selected questions that emerged as relevant in each country. We translated the questionnaire for Senegal into French.

The process of collecting data took place during restrictions imposed to contain the Covid-19 pandemic in the three countries. The situation is likely to have affected data collection in a number of ways. Most participants could not come to their offices. Individuals often have worse access to internet and general working conditions at home than at the office. They may not be able to devote as much time and attention in the presence of competing responsibilities and uses of space at home as they may have been able to in the office. The situation may have reduced participation in the study and it may have particularly impeded participation by those who do not have access to the internet at home and whose living conditions are generally more modest.

The information about the institutional structure of the national planning processes comes partly from interviews and partly from a review of national documents by the research teams in each country. The documents and the expertise of country research team members are the sources of information for institutional maps in Section 3.

Methods
We audio-recorded the interviews and transcribed the audio recordings. We analyzed the transcripts by identifying the main themes that emerged under each category of questions. The categories of questions were:

- The main vulnerabilities and adaptations in the agricultural sector on which the respondent's work is focusing
- Successes in national climate change planning for agriculture
- Obstacles to national climate change planning and adaptation in agriculture
- Sources of influence in the national planning processes
- Information that respondents have been using in their work related to climate change in agriculture
- Obstacles to use of existing information
- Information needs
- Needs for new research
- Impacts of the pandemic on the respondents' work and on national planning processes

We organized components of transcripts by the themes, which they illustrate. We report points that were mentioned by three or more respondents in each country.

For most survey questions, we report the percentage of respondents who selected each answer option. Exceptions are questions shown in Figures 9 and 10, in which we report the percentage of times that a particular category of organization is mentioned. For the survey questions for which answer options differ across countries, we group the answer options that differ into broader categories in the figures in the main sections of the report, in which we document results for all three countries. For these questions, we report individual results for each country in the appendices.

Survey respondents
Seventy-six percent of survey respondents say that they are or have been involved in climate change and/or adaptation planning processes for agriculture in their countries. The percentage

varies from 63% in Ghana, to 78% in Senegal, to 88% in Zimbabwe. A third to a half of the survey respondents represent government organizations, depending on the country. The second most common institutions are national academia, followed by national research organizations, international development and technical assistance organizations, civil society organizations and national NGOs, international NGOs, and very few individuals from the private sector. The majority of respondents are at the senior levels of their organizations, with somewhat greater representation of middle and junior levels in Zimbabwe. Respondents fulfill a range of responsibilities, with the most frequently mentioned roles being program implementation, capacity building, coordination, and planning. They represent a range of areas of expertise, with the most frequently listed areas being vulnerability and adaptation to climate change, project management, and environmental management. Figures A.11 to A.14 in Appendix A.5 show the respondents' characteristics.

3. Institutional structure of the national climate change planning processes

This section outlines the structure of the national climate change planning processes in Ghana, Senegal, and Zimbabwe. In all three countries, a national government mandate exists for national climate change planning. The responsibility for leading the planning processes and approving them lies within a single national government ministry in each country. Broadly, the leading ministries set planning priorities, though in consultation with others, they approve planning processes, and they draft and approve plans. The leading ministries work with other national government ministries, departments, and directorates that are responsible for sectors and/or functions that are directly or indirectly vulnerable to climate variability and change. The ministries of agriculture play an important role in planning for the agricultural sector even when they are not the leading ministry.

All three countries participate in international agreements on climate change, including the African Ministerial Conference on the Environment (AMCEN), Southern African Regional Climate Outlook Forum (SARCOF), the UNFCCC, and the Paris Agreement, among others. These agreements play a role in shaping the national planning processes. An interview respondent in Senegal notes that the National Adaptation Programs of Action (NAPA) process was the catalyst for the focus and work on climate change and adaptation in Senegal. All three countries have developed and submitted to the UNFCCC their Nationally Determined Contributions (NDCs) and are developing NAPs.

In all three countries a number of actors other than the national government play important roles in the planning processes. These organizations and their roles include:

- International development and technical partners offer research and technical expertise as well as funding. The partnerships influence the planning process through information and research capacity provided as well as by funding particular priorities, often with conditions on the use of the funds. Progress in national planning and implementation of adaptations would be difficult without external funding in each country.

- Research organizations, including academia, provide information to the planning processes such as climatology and analysis of how the climate has been changing, future climate projections, vulnerabilities to climate variability and change, and research on adaptation. Respondents in all three countries emphasize that research is influential. The lead ministries partly influence the available research by requesting and funding research on particular topics. However, much of the research is driven by universities and external funding consortiums, while the government ministries collate the research outputs and apply some of the research.

- Regional and local government bodies are responsible for implementing adaptation approaches and supporting farmers and other private organizations and individuals in adopting adaptations, following the guidelines established in the national plans. Also, local government is a source of information about manifestations of climate change and impacts at the local level, and potential adaptation strategies, which may be tested and scaled up elsewhere in the country.

- Elected officials at national and local levels can play a role in the planning processes by shaping relevant legislation, by forging consensus around issues to be addressed, and by communicating scientific information and local experience between the national and local levels. They receive mention in interviews in Senegal but not in the other two countries.

- Civil Society Organizations (CSOs) and non-profit non-government organizations (NGOs) as well as traditional leaders participate in the planning process as advocates for particular social groups, sources of information about challenges at the local level and emerging solutions that can be adopted elsewhere, and communicators between the national and local level. They have a voice in the planning processes but not the ability to make decisions. Also, these organizations can serve as partners in implementing adaptations.

- Private for-profit sector has a potentially important role to play in adaptation planning but does not seem to be involved in the process yet, except to some extent in Senegal.

- A respondent in Ghana mentions the potential role of the financial sector. Banks, insurance companies, and other financial institutions could advance adaptation planning and implementation by providing funding for adaptation efforts, and by requiring evidence that vulnerabilities to climate change have been understood and planned for as a condition for funding. However, the sector does not seem to be playing this role yet.

The specific distribution of responsibilities and roles across the different actors varies from country to country. We describe the general structure and main institutions involved in each country below. A detailed discussion of roles and responsibilities is beyond the scope of this report.

3.1 Ghana

The lead institution for the national climate change planning process in Ghana is the Environmental Protection Agency (EPA), which is the climate change implementation arm of The Ministry of Environment, Science, Technology and Innovation (MESTI). EPA and MESTI play a leading role in setting priorities, guiding planning efforts, and drafting and approving plans. The EPA and MESTI work closely with the Forestry Commission, which is part of The Ministry of Lands and Natural Resources, and the Crop Services Directorate of The Ministry of Food and Agriculture (MoFA), which is charged with the coordination and reporting of issues related to climate change in agriculture to the EPA. MoFA houses the extension services and works directly with farmers and users at the district level. These ministries develop relevant legislation and regulations, and they steer implementation efforts. The National Development Planning Commission (NDPC), which is part of the executive, plays an important role at a high, strategic level since it is legally mandated to regulate the planning system. NDPC issues statutory guidelines, and they approve plans. NDPC approval is required in order for the Ministry of Finance to release funding.

The above ministries work closely with other government departments and agencies at the national and local levels, development and technical partners, research organizations, and civil society organizations bilaterally and through coalitions, which the report discusses in more detail in Section 4.2. Figure 1 shows an idealized representation of the main participants in the planning processes according to their policy influence and their technical and/or scientific expertise, developed by the AgMIP research team in Ghana. Policy influence affects the stakeholders' ability to shape the planning process, plans, legislation, and implementation. Expertise determines the extent to which the stakeholder can create knowledge and/or interpret and use technical or scientific information for decision making. The map shows all groups of stakeholders who participate in the process. The information in this section is based on EPA (2013, 2018), Ministry of Environment, Science, Technology and Innovation (2015), and Republic of Ghana (2015).

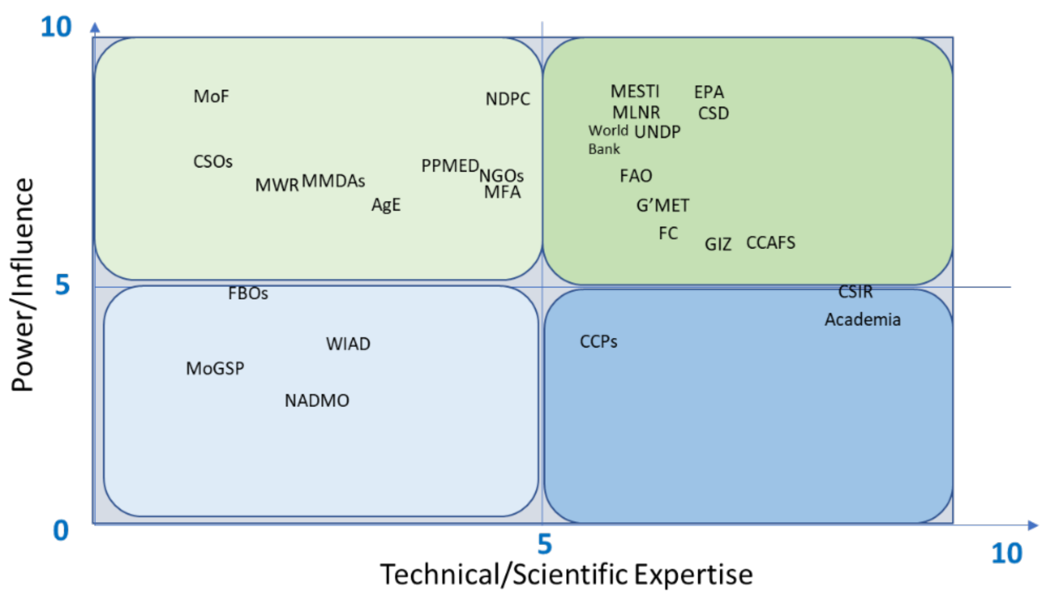

Figure 1. Stakeholder map – Ghana
Developed by the AgMIP team in Ghana in consultation with local partners.
MoF: Ministry of Finance; NDPC: National Development Planning Commission; CSOs: civil society organizations; MWR: Minstry of Water Resources; MMDAs: Metropolitan, Municipal and District Assemblies; PPMED: Policy Planning Monitoring and Evaluation Directorate;

NGOs: non-profit non-government organizations; MoFA: Ministry of Food and Agriculture; AgE: Agriculture Extension; MESTI: Ministry of Environment, Science, Technology and Innovation; EPA: Environmental Protection Agency; MLNR: Ministry of Lands and Natural Resources; CSD: Crop Services Directorate; UNDP: United Nations Development Program; FAO: Food and Agriculture Organization; G'MET: Ghana Meteorological Agency; FC: Forestry Commission; GIZ: Deutsche Gesellschaft für Internationale Zusammenarbeit; CCAFS: Consortium of International Agricultural Research Centers (CGIAR) Research Program on Climate Change, Agriculture and Food Security; FBOs: Farmer Based Organizations; WIAD: Women in Agriculture Development, unit of MoFA; MoGSP: Ministry of Gender, Children, and Social Protection; NADMO: National Disaster Management Organisation; CSIR: Council for Scientific and Industrial Research; CCPs: Climate Change Programs.

3.2 Senegal

The leading ministry in charge of national climate change planning for agriculture is The Ministry of the Environment and Sustainable Development. The Ministry coordinates the national climate change planning process. It develops and implements policy, approves regulations, and drafts and approves national plans and reports. The Ministry works closely with the Ministry of Agriculture and Rural Equipment, consisting of its cabinet, the Directorate of Agriculture (DA), the Senegalese Agricultural Research Institute (ISRA), and the Senegalese Directorate of Analysis, Forecasting and Agricultural Statistics (DAPSA). The Ministry of Agriculture has the mandate to develop agricultural policy, including policy that addresses climate change.

A number of mixed groups, which function as coalitions, have been created by the government and play important roles in the planning process. The National Committee to Combat Climate Change (COMNACC) supports the negotiation, preparation, and definition of policies related to climate change and adaptation. COMNACC also helps communities to develop fundable projects that address climate change issues, and coordinates regional actions on climate change. The DA houses The Science-Policy Dialogue on the Adaptation of Agriculture and Food Security to Climate Change (CCASA) platform, which was created to bring together stakeholders to discuss the planning process and ensure that concerns of many stakeholders and sectors inform the process. Executive Secretariat of the National Council for Food Security (SECNSA), housed in the Office of the President, is another body that plays an important role in the planning process.

The government ministries work closely with a number of other stakeholders. Interview respondents in Senegal note the important role of elected officials who are familiar with climate change and adaptation issues in agriculture and who can bring evidence from the local level into discussion with the national government. Elected officials have created The Network of Parliamentarians for Environmental Protection (REPES) to influence the planning process. Development and technical partners, research organizations, and civil society influence the process. Senegal is the only one of the three countries in which agribusiness is becoming influential.

The study team in Senegal developed an idealized representation of important participants in the national planning processes in Senegal shown in Figure 2 and the list shown in Table 1. The table does not include all participants in the planning process. The information in this section is based on République du Sénégal (2014, 2020), Ministère de l'Environnement et de la Protection de la Nature (2006), Faye et al (2019).

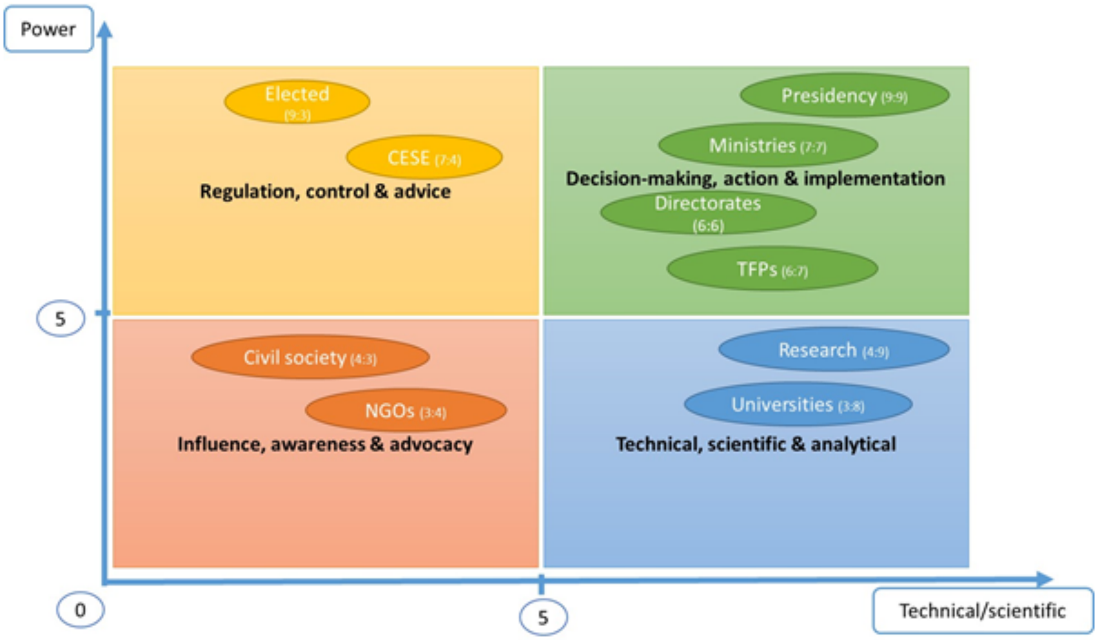

Figure 2. Stakeholder map - Senegal

Developed by the AgMIP team in Senegal in consultation with local partners.

CESE: Economic, Social and Environmental Council; TFPs: technical and financial partners

Presidency • Executive secretariat of the national council for food security (SECNSA) • Malnutrition Control Unit (CLM)	**Ministry of Agriculture and Rural Equipment** • Agriculture Directorate (DA) • Senegalese Agricultural Research Institute (ISRA)	**Elected officials** • Parliamentarians • Economic, social and environmental council (CESE) • High Council of Local Authorities (HCCT)
Ministry of the Environment and Sustainable Development • Department of the Environment and Classified Establishments (DEEC) • National Committee to Combat Climate Change (COMNACC)	**Ministry of Economy, Planning and Cooperation** • National Agency for Statistics and Demography (ANSD) • National Agricultural Insurance Company of Senegal (CNAAS)	**Civil Society** • National Council for Consultation and Cooperation for Rural People (CNCR) • Union of Associative and Community Radios (URAC)

Ministry of Animal Husbandry and Productions • Livestock Department (DIREL)	**Ministry of Tourism and Air Transport** • National Agency for Civil Aviation and Meteorology (ANACIM)	**Technical and Financial Partners** • FAO * UNDP/FEM • UNDP/GEF • AFD * WB • GIZ * UN WOMEN • USAID
University and Research • CERAAS • IED AFRIQUE	**Private sector** • Geomatica • Agricultural Bank	

Table 1. Key stakeholders in the national climate change planning process for agriculture in Senegal

FAO: Food and Agriculture Organization; UNDP/FEM: United Nations Development Program Fonds pour l'Environnement Mondial; UNDP/GEF: Global Environment Facility; AFD: Agence Française de Développement; WB: World Bank; GIZ: Deutsche Gesellschaft für Internationale Zusammenarbeit; UN Women: United Nations Entity for Gender Equality and the Empowerment of Women; USAID: United States Agency for International Development; CERAAS: Centre d'Etude Régional pour l'Amélioration de l'Adaptation à la Sécheresse; IED Afrique: Innovation Environnement Dévéloppement Afrique

3.3 Zimbabwe

The leading ministry in climate change planning in Zimbabwe is the Ministry of Environment, Climate, Tourism and Hospitality industry (MRCTHI), and the unit within the Ministry that is in charge of directing, coordinating, and approving planning and implementation of work related to climate change and adaptation is The Climate Change Management Department (CCMD). Interview respondents report that the Department is the critical conduit of much of the funding available for work on climate change, serving as a Focal Point/Nationally Designated Authority/Nationally Designated Entity for international funding and other technical assistance processes. The Department works closely with other government agencies such as the Ministry of Lands, Agriculture, Water and Rural Resettlement (MLAWRR) and its agricultural extension arm, Department of Agricultural, Technical and Extension Services (AGRITEX), Economics and Markets, Department of Research and Specialists Services (DRSS), Zimbabwe National Water Authority (ZINWA) and other departments such as the Department of Civil Protection (DCP), Meteorological Service Department, The Environmental Management Agency (EMA), the IDBZ, Ministry of Finance and Economic Planning, Ministry of Foreign Affairs as well as the Parliament of Zimbabwe from the Government side.

Two platforms that bring together many stakeholders have been established by the government in Zimbabwe to help shape the climate change planning and action processes. The Zimbabwe United Nations Development Assistance Framework (ZUNDAF) is an agreement between the UN and the government of Zimbabwe through which UNDP, in particular, and the government establish climate change priorities for the next five years. The agreement has indicators and guides the UNDP assistance. The Zimbabwe Resilience Building Fund (ZRBF), a long term development initiative funded by multiple donors, engages multiple stakeholders to build resilience in communities to climate variability and change and extreme events.

As in the other two countries, The Climate Change Management Department works closely with other stakeholders, in particular development and technical partners, research organizations, and civil society. The study team in Zimbabwe developed the idealized representation of stakeholder roles and influence dynamics in climate change planning for agriculture in Zimbabwe shown in Figure 3. The map does not include all participants. The information in this section is based on Bhatasara 2018; Brazier 2015; CIAT and WB 2017; CTCN 2017; Dube 2017; Echanove 2017; EMA 2019; Frischen et al 2020; Chitiyibo et al 2019; MLARR 2019a, b; MLARR 2018a, b, c; Mugandani et al 2012; Scoones 2018; UNDP 2019, 2018, 2016; WB 2019a, b; Zimbabwe's Intended Nationally Determined Contribution (INDC), ZimVAC 2019; ZimStat 2017.

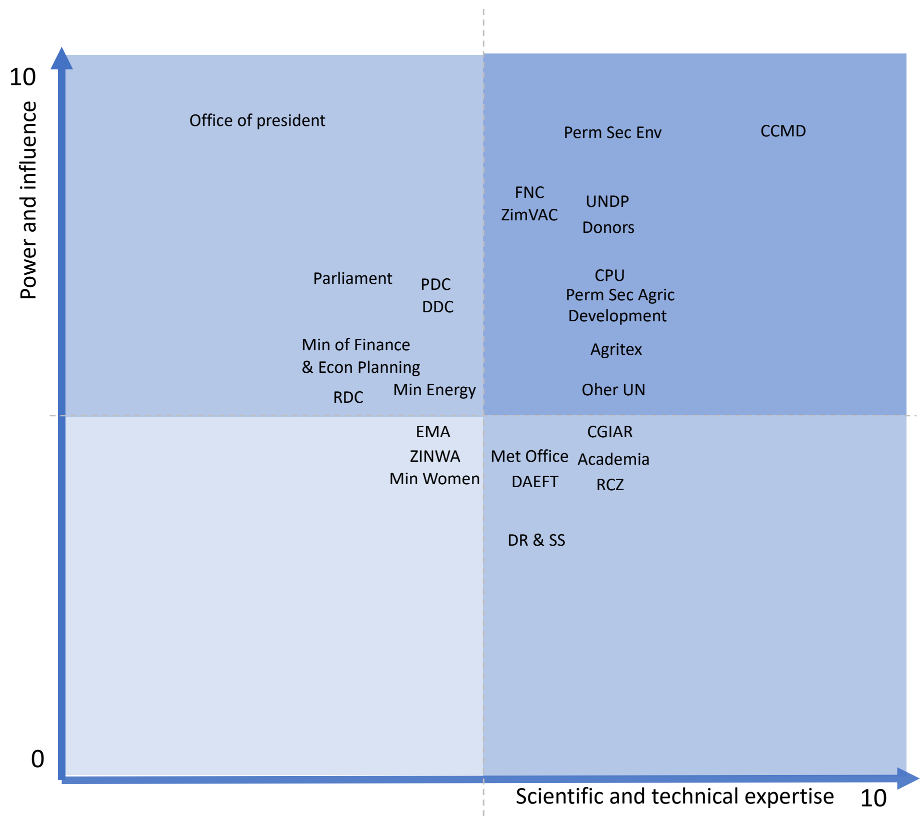

Figure 3. Stakeholder map - Zimbabwe

Developed by the AgMIP team in Zimbabwe in consultation with local partners. FNC/ZIMVAC: Food and Nutrition Council/ Zimbabwe Vulnerability Assessment; UNDP: United Nations Development Program; PDC, DDC: district and provincial development committees; CPU: Department of Civil Protection; RDC: Rural District Council; EMA: Environmental Management Agency; ZINWA: Zimbabwe National Water Authority; DAEFT: Department of Agricultural Education and Farmer Training; CGIAR: Consortium of International Agricultural Research Centers; RCZ: Zimbabwe Research Council; DR & SS: Department of Research and Specialists Services

4. Progress in and obstacles to national climate change planning for agriculture

4.1 Priorities in national planning processes

Respondents from all three countries emphasize that the national climate change planning processes place a particularly strong emphasis on the agricultural sector. The sector is critical for the economies and livelihoods, and its performance has a major influence on the central concern about food security. Furthermore, awareness and consensus that the agricultural sector is highly vulnerable to climate variability and change has grown considerably in recent years, particularly within the national governments, although climate risk and environmental degradation continue to rank below other challenges to the agricultural sector in each country, as Figure 4 illustrates based on survey responses.

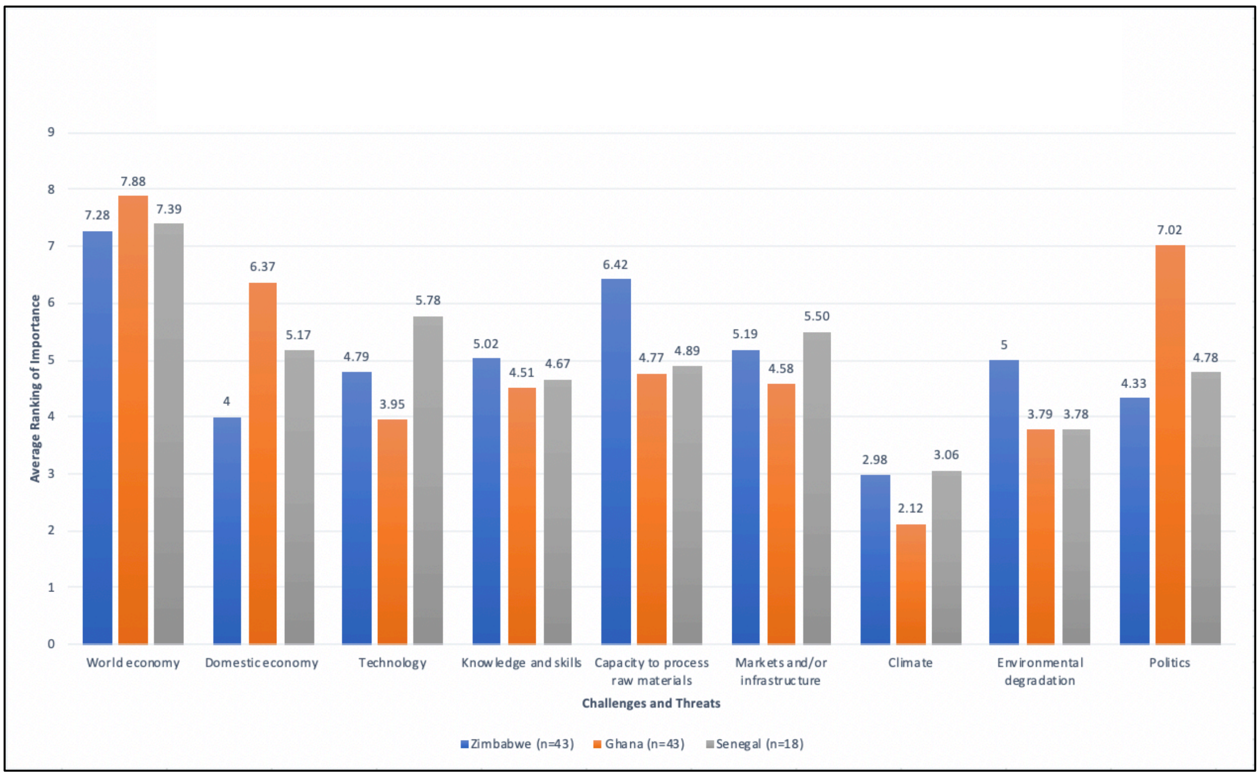

Figure 4. Ranking of challenges and threats to the agricultural sector based on their importance

Data are from baseline survey. Respondents ranked each challenge relative to the others from 1 (most significant) to 9 (least significant).

A complementary observation emerges from interviews that the vulnerability of the agricultural sector is integrated with the performance of other sectors, such as water, energy, transportation, and other dimensions of the food system, such as storage,

processing, markets and factors that influence demand. Progress on adaptation depends on fully understanding the linkages between the vulnerabilities in the sectors and on planning and implementation that is coordinated across different sectors.

Vulnerability to climate change

Especially in Senegal and Zimbabwe, stakeholders who are involved in national climate change planning report that understanding vulnerability has been an important part of the process thus far. A number of interviewees emphasize that identifying and designing adaptation strategies is not possible without a thorough understanding of the vulnerabilities of the connected biophysical and social system presently and in the future, taking climate change into account. The role that understanding vulnerability plays in planning is less salient in interviews with Ghanaian stakeholders, but they emphasize the need for more research on vulnerability. On a Likert scale of 1 (understanding is poor) to 7 (understanding is very good), survey respondents report that the understanding of vulnerabilities is around 4 in Ghana and Zimbabwe and 4.5 in Senegal, suggesting that work remains to be done on this front.

The definitions of vulnerability vary somewhat in the literature. This report uses the following definition. Vulnerability includes (1) exposure to a hazard, (2) susceptibility to be impacted by that exposure, negatively or positively and (3) ability to recover from any negative impacts (Cutter et al 2009). Hazards can vary in speed of onset and duration from sudden and short-term, such as flooding, to slow and long-term such as climate change. The impacts of climate variability and change are included in vulnerability under the second point.

Impacts of climate on food security are the vulnerability to climate change on which most survey respondents are focusing in their work in the agricultural sector in each country. Impacts on livelihoods are second most important, except in Senegal. Combined categories of drought and heat impacts and moisture availability are third, except in Ghana where changing and unpredictable weather patterns receive more attention. Productivity receives relatively little attention. Figure 5 shows the importance of a number of vulnerabilities mentioned by survey respondents as reflected in the number of respondents who list the vulnerability as one of the three most important ones that they are focusing on in their work.

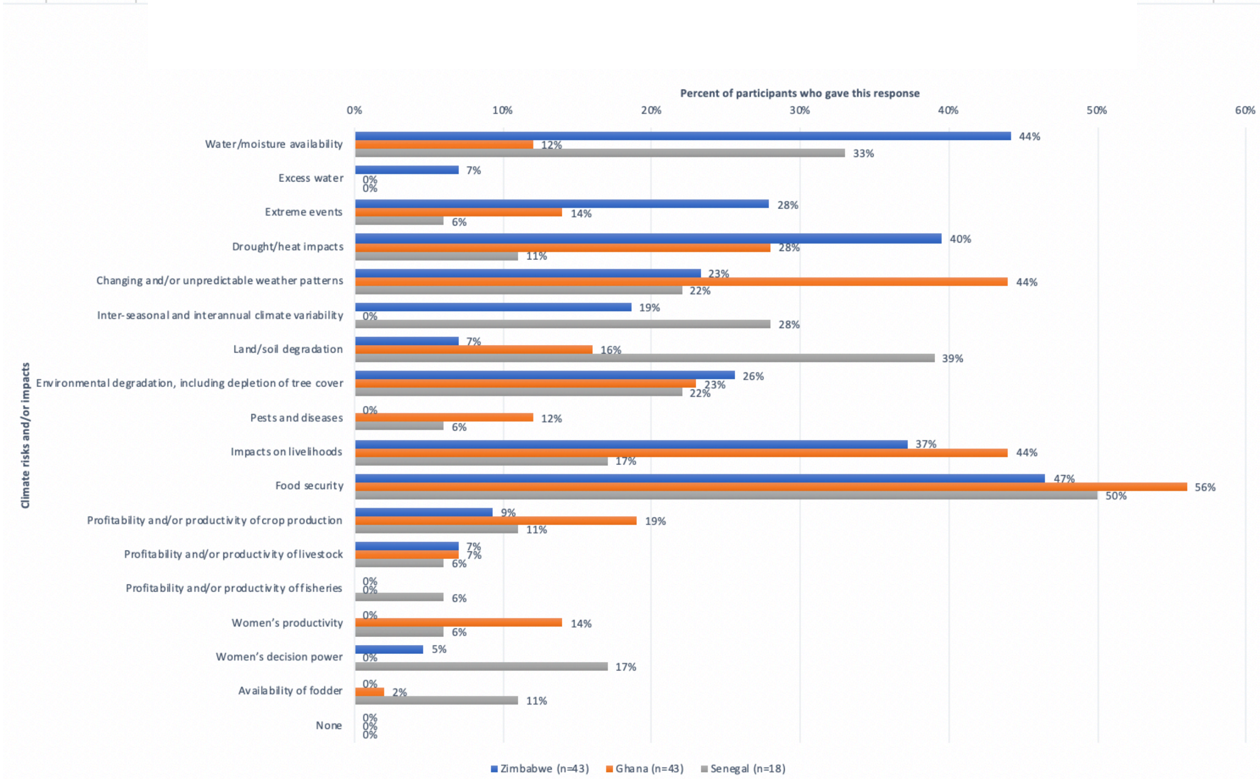

Figure 5. Climate risks and/or impacts identified as being among the main three on which respondents are focusing in their work in the agricultural sector
Data are from household surveys. Respondents could select up to three responses; therefore percentages of respondents who give each answer do not add up to 100% for each country.

In interviews, respondents from all three countries identify water availability as perhaps the major component of vulnerability in the agricultural sector on which the planning process is focusing. Agriculture in all three countries depends mainly on rainfall. The primary hazards reported by interviewees are changes in rainfall distribution across time and space, unpredictable rainfall patterns and intensity, and insufficient rainfall. Respondents in Senegal and Zimbabwe particularly mention that mid-season dry spells cause problems. Respondents in Senegal also mention false and late starts of the rainy season, and early or late end to the rainy season. In Senegal and Zimbabwe, flooding is also an issue in some areas.

Additional hazards consist of increasing maximum temperatures as well as more extreme minimum temperatures, which cause frost and horticultural losses in winter especially in Zimbabwe. Rising temperatures combine with shorter and/or erratic rainy seasons to cause desertification and loss of biodiversity and biomass.

A principal damage from these exposures that is salient in the planning process is loss of food security, as highlighted in the survey results, through reduced yields, livestock, and fish causing reduced number and diversity of meals as well as damage to stages of value chains other than production of food. Water availability affects livestock directly and indirectly, through production of feed. Respondents mention reduced access to fruit and vegetables, which negatively impact nutrition security, income generation and livelihoods. Damages that contribute to reduced food security include new pests and/or diseases and/or change in their frequency and distribution and environmental degradation. Respondents in Zimbabwe and Ghana mention depletion of tree cover and loss of non-tree forest products, such as herbs, spices, and snails, which contribute to dietary diversity in both countries.

Beyond food security, there is concern about damage to incomes and livelihoods. Respondents in Ghana and Zimbabwe mention that women are particularly vulnerable partly because they rely on components of the agricultural system that are most prone to damage, such as vegetable gardens as well as forest products. In Zimbabwe, interviewees say that women are particularly vulnerable because they compose about 70% of smallholder farmers, who themselves are the large majority of the population. Many other factors beyond those discussed in interviews contribute to the vulnerability of women farmers.

Adaptation to climate change

We define adaptation as the process through which society adjusts to climate change. Adaptation includes coping and mitigation strategies that help to maintain and/or improve socio-economic functions and livelihoods in the presence of a changing climate (Noble et al 2014).

The focus on adaptation strategies in the national planning processes reflects the salient vulnerabilities in that the adaptation strategies that receive most attention aim to influence food security and livelihoods through various parts of the food systems. The main adaptation options that survey respondents are focusing on in their work in the agricultural sector are improving farmers' capacity to understand climate risks and adaptation options in Ghana and Senegal, and measures to improve moisture availability as well as climate information services that can help farmers and other stakeholders to make production decisions in Zimbabwe, as shown in Figure 6. On a Likert scale of 1 (understanding is poor) to 7 (understanding is very good), survey respondents report that the understanding of adaptation measures that are needed in agriculture is around 3.5 in Ghana and Zimbabwe and 4 in Senegal, somewhat below the understanding of vulnerabilities. Respondents rank progress on implementing adaptation measures at 3 in Zimbabwe and 4 in Ghana and Senegal on a Likert scale of 1 to 7, where 1 indicates that implementation of adaptation measures has not begun while 7 indicates that implementation of adaptation measures is advanced.

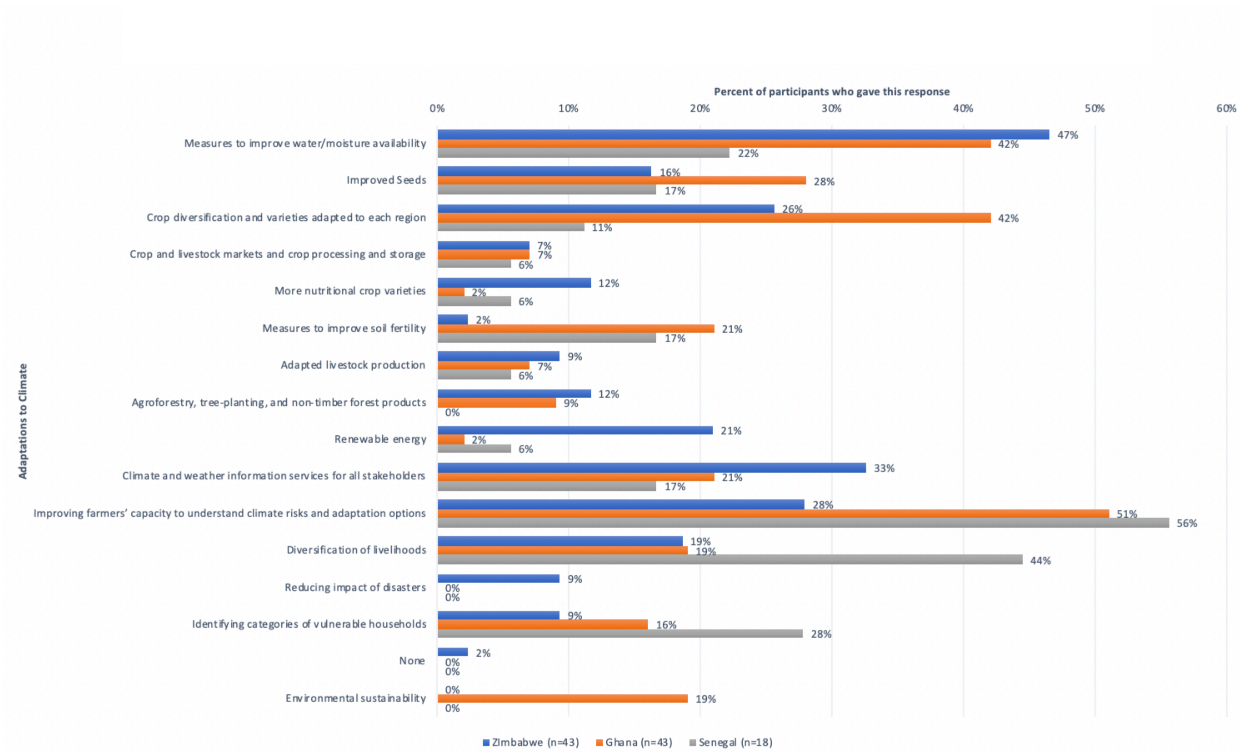

Figure 6. Adaptations identified as being among the main three on which respondents are focusing in their work in the agricultural sector
Data are from baseline surveys. Respondents could select up to three responses; therefore percentages of respondents who give each answer do not add up to 100% for each country.

In interviews, many respondents mention climate-smart agriculture. The adaptation strategies that interviewees emphasize the most aim to manage water and conserve moisture. Strategies include water harvesting, water-saving irrigation, and small dams for household use. Other prominent production-oriented strategies include managing soil fertility; developing seeds that are well adapted to type of soil and present and future environmental conditions in sub-regions of the countries, for example crops that can mature in a short rainy season; developing livestock breeds and pasture crops that are similarly well adapted; diversifying the crops that farmers plant; climate-smart technologies; and agroforestry. Ensuring that farmers have access to information requires improving extension services.

Some adaptation strategies that participants in the planning process mention focus on non-production parts of the food system. They include improving storage, processing, functioning of markets, changing behavior to diversify livelihoods and diets, and expanding social protection. Improving the nutritional value of diets arises especially often in interviews from Zimbabwe.

> *"I believe that we should talk about preserving the productive base of family farms, because everything is centered around this issue. It is true that, beyond this aspect, we should ensure an effective marketing after the production. But what is*

more central and critical at the moment is really the preservation of the productive base. And when we talk about the productive base, it's global. It goes from the land to the seeds, the water, the forests."
Interviewee from Senegal.

4.2 Successes in national climate change planning for agriculture

The national climate change planning processes are in early stages in all three countries. Respondents in each country report that the process has just begun to take the first steps. However, each country has also achieved important milestones.

In Ghana and Zimbabwe, most survey respondents note the existence of national climate change policy and awareness of climate change impacts and vulnerabilities as the main successes in the national planning processes for climate change in the agricultural sector thus far. Survey respondents in Zimbabwe also note climate change response strategy and the development of the Climate Smart Agriculture (CSA) manual and framework as impactful, positive developments. In Senegal, most respondents note awareness of climate change impacts, vulnerabilities, and adaptations; consultative processes in the country; and several projects that are advancing adaptation. Figure 7 shows the main successes reported by survey respondents.

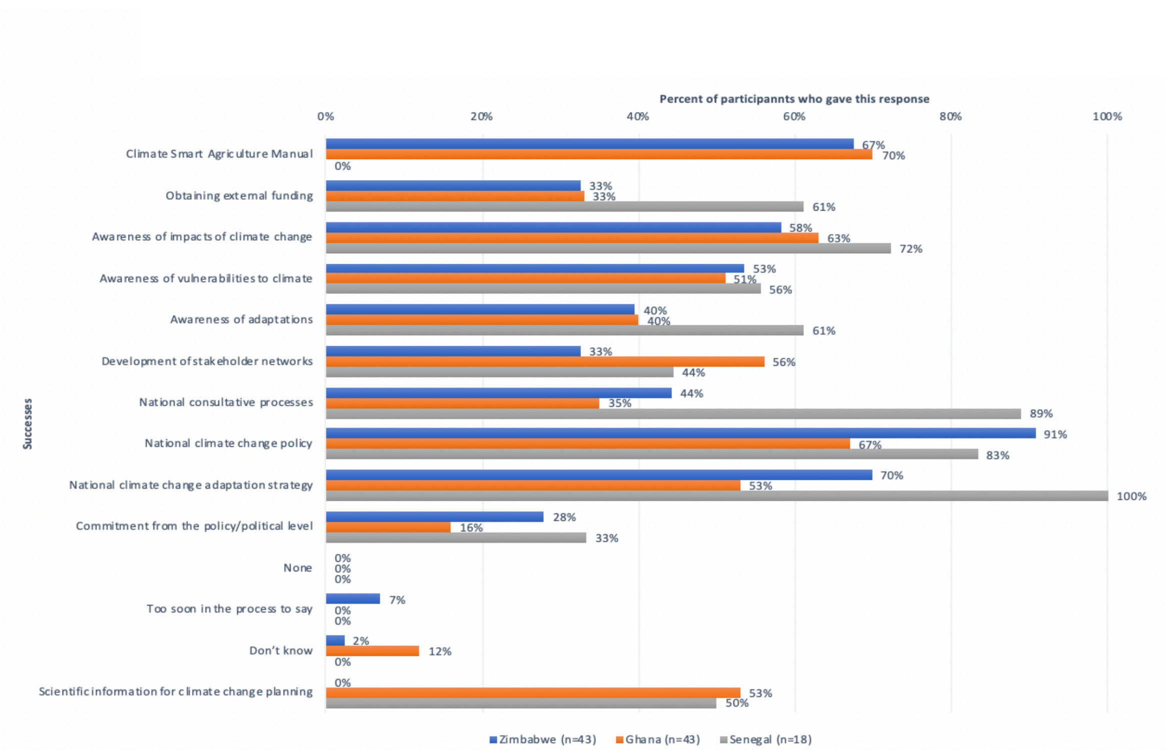

Figure 7. The main successes thus far in national planning for climate change in agriculture
Data are from baseline surveys. Respondents could select multiple responses; therefore percentages of respondents who give each answer do not add up to 100% for each country.

Interviewees in each country report increased awareness about climate change, its impacts, and the potential for adaptation among a range of actors, and especially at the national government level, consistently with the survey. Interview respondents in all three countries mention increased interest and commitment from the political level to enact policies that advance climate action including adaptation to climate change in the agricultural sector.

Interviewees cite the development of national policies and strategic documents that guide planning and practice for climate change adaptation in agriculture as important steps forward. The process of developing the documents has required the attention of many organizations and individuals, for whom, as a result, planning for climate change in agriculture has become a greater priority. Participation in developing the policy and strategic documents has contributed to the creation of coalitions and discussion platforms that have continued to advance the planning process as well as implementation. Developing the content of the documents has required research on vulnerabilities to climate change in agriculture and potential adaptation strategies and pathways, generating broader awareness and deeper understanding of the problems that need to be addressed. The development of documents has generated support in terms of research and funding from international development and technical partners. Finally, the documents guide further action, helping to coordinate efforts around certain priorities.

> *"What it [the national climate change policy framework] says I can't say on top of my head. But what it does. It brings funding from development partners. Even if it's not funding, some kind of collaboration or partnership based on the way it has been done and then we've had all these monies, Green Climate Fund and stuff also coming in into the process. So, I think that it has helped because it has targeted and focused what we do."*
> *Interviewee from Ghana*

In Senegal, the respondents mention that the country was one of the first to develop the Technology Action Plan for Adaptation for agriculture. An important early document, developed in 2014, was the Program of Acceleration of the Production Pace in Senegalese Agriculture (PRACAS), which emphasized addressing obstacles to progress in agriculture, including climate variability and climate change. Other influential documents include Plan for an Emerging Senegal (PSE), developed around the same time as PRACAS, a guide for climate change planning at the local level based on manuals developed by the German agency for international development, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), and the National Adaptation Plan for Action (NAPA) first published in 2006.

In Ghana, the stakeholders whom we interviewed mention especially The Climate-Smart Agriculture and Food Security Action Plan, developed in 2015, as an example of progress in national climate change planning for agriculture. The planning process began in Ghana with the National Climate Change Adaptation Strategy in 2012, which included the Akropong approach that has been adopted elsewhere. Other examples from Ghana include the National Climate Change Policy, developed in 2013, which was an important starting point, the Nationally Determined Contributions finalized in 2015, National Adaptation Plan Readiness Proposal submitted to the Green Climate Fund in 2017, and the National Adaptation Plan Framework completed in 2018, which the respondents report as being cited by many countries.

In Zimbabwe, respondents particularly mention The Climate-Smart Agriculture Manual for Agriculture Education in Zimbabwe, published in 2017, as significant progress toward improving adaptation in the agricultural sector. They identify the Climate Change Response Strategy developed in 2014 and the National Climate Policy completed in 2017.

Almost all interviewees discuss the importance of coalitions and collaboration platforms for advancing climate change planning and action in agriculture. The coalitions and platforms for dialogue and consultation bring a range of expertise into the process, information about needs, information about experience with adaptation, approaches that worked and did not work, challenges, obstacles, and opportunities from stakeholders from across the country and levels of society. The coalitions and consultations engage different channels of influence that have varied means of promoting progress. Also, importantly, they help to coordinate efforts to use scarce resources more efficiently. Most respondents mention that broad participation has been critical to the achievements attained until now.

> *"… these are frameworks that allow the concerns of both sides to be taken into account; there is a lot of exchange, there is intersectoral dialogue: the dialogue between livestock, the environment and agriculture. There are constructive dialogues that take place within these frameworks because they allow us to discuss actions, to undertake and avoid duplication, and to discuss funding opportunities. These are frameworks that together make it possible to be strong to be able to acquire funding, to be able to think about strategies."*
> *Interviewee from Senegal*

> *"I believe that it is above all the participatory approach that is at the origin of this success."*
> *Interviewee from Senegal*

> *"… engagement by many stakeholders has been an important component of success."*
> *Interviewee from Zimbabwe*

> *"One of the successes is a well-established network among stakeholders because most of the time we talk of the technical stuff forgetting about the governance aspect without which the technical aspect will not work."*
> *Interviewee from Ghana*

Respondents in Senegal uniformly emphasize the creation of the National Climate Change Committee (COMNACC) in 2011, which has played an important role in coordinating various stakeholders, bringing various voices to the table, and advancing important national documents, such as PRACAS and PSE. They also mention the importance of decentralized planning through the Regional Climate Change Committees (COMRECCs), and the participation achieved through National Science Policy Dialogue Platform for Adaptation to Climate Change (CCASA), the

Climate Resilience Directorate, and the Executive Secretariat of the National Council for Food Security (SECNSA).

In Ghana, interviewees give the example of District CSA Platforms established by the Ministry of Food and Agriculture in collaboration with CCAFS under the auspices of District Assemblies. The Platforms serve as consulting and coordinating bodies that support District Assemblies in implementing adaptation actions. The Ghana Climate and Space Institute contributes to the Rainwatch Africa platform, which provides information for Ghana and 15 other African countries. They also engage various stakeholders to share information and experience to ensure that farmers ultimately receive reliable information.

In Zimbabwe, various platforms involve a variety of stakeholders, coordination frameworks and collaborations. The Zimbabwe Vulnerability Assessment Committee (ZimVAC), coordinated by the Food and Nutrition Council (FNC), has been conducting coordinated rural and urban livelihood and vulnerability assessments annually. The ZimVAC assessments guide policies and programs that respond to the prevailing food security situation. The Zimbabwe United National Development Framework (ZUNDAF) is a platform for coordination between UN agencies and stakeholders to support national development priorities. The Zimbabwe Resilience Building Fund (ZRBF) is an important development initiative that generates and integrates evidence for program targeting, policy making, community capacity building, and emergency response mechanisms. There is a National Climate Change coordination structure which is provided for in the National Climate Change Response Strategy (NCCRS) and the National Climate Policy (NCP), which coordinate the policy development and implementation of key climate interventions such as the revision of the NDCs, recommending approval of funding proposals, and facilitating provision of data and other support to enhance climate action. Recently, Zimbabwe has also developed the Green Climate Fund (GCF) Country Programme, which enhances climate action through guiding the development and implementation of climate projects as well as defining the immediate and long term climate gaps and priorities. A number of other collaborations have been important to the planning process and to action such as UNDP coordinating with the National Adaptation Readiness project and with ZRBF.

Research has contributed substantially to achievements in all three countries by helping to develop the national climate change planning documents and processes as well as informing funding applications through feasibility studies and/or provision of novel research outputs. In Senegal, research that supported the development of NAPA showed the strong impact of climate variability on the agricultural sector. Vulnerability assessments created by a number of projects such as Scientific Support Project for the National Adaptation Plan (PAS-PNA), Strengthening Agricultural Adaptation (SAGA) Senegal (FAO project), and UNDP projects have played a critical role in informing the national processes. Projects that focused on particular regions have enabled local authorities to integrate climate change into communal development plans, for example the PREDA Fatick project in the Fatick region and to understand resilience options, such as the research on resilience carried out under Project to strengthen the resilience of Ferlo ecosystems (PREFERLO). An example from Ghana are the climate projections developed by the Climate and Space Institute, which inform policy at the national level. In Zimbabwe, early research by Zero Regional Environment Organization on climate impacts, role of gender, and economics of climate adaptation resulted in the NCCRS. The development of the INDCs was founded on key research outputs from multiple researchers including Vulnerability and Adaptation teams of the National Communications, Coping with Drought Project in Chiredzi. Detailed feasibility studies and research, which documented climate vulnerability based on observed climate and projected climate trends and impacts in agriculture, resulted in approval of the GCF UNDP FP 127 and WFP SAP 007 projects. On the policy front, the national climate policy and Water Resource Master Plan were all informed by stakeholder consultations and research, especially on projected climate scenarios.

Additional evidence of successes consists of recognition and funding from the UN and other international development and technical partners. Research has helped to attract funding from the GCF, which requires that funding proposals demonstrate that the problems being addressed are caused by climate change. Respondents in Zimbabwe note the accreditation of the Environmental Management Agency by the Adaptation Fund, which resulted in increased flow of funding. Interviewees in Zimbabwe discuss the importance of training in development and writing of fundable proposals, and they note that the training received from UNDP has resulted in significantly more funding from the Adaptation Fund and the Green Climate Fund. The development of key documents in Zimbabwe, such as The CSA Manual and other policy documents were funded by the Climate Technology Centre and Network, the technology arm of the UNFCC, by Common Market for Eastern and Southern Africa (COMESA), UNDP, and UNEP. As a respondent from Ghana emphasizes, successful development of national documents also attracts international funding.

Another example of progress includes allocating the national budget to address climate change issues in agriculture, for example 10% in Senegal. However, survey respondents rank the importance that adaptation to climate change in the agricultural sector receives in the national budget at around 3 in Ghana and Senegal, and just below 4 in Zimbabwe, on a scale of 1 to 7.

Interviewees, especially in Senegal and Zimbabwe, note that good leadership is essential for progress in planning and action. A respondent in Zimbabwe offers the example of developing The Climate-Smart Agriculture Manual for Agriculture Education in Zimbabwe. The long, complex process included writing a proposal, which won funding from UNFCCC's Technology Mechanism Operational arm, Climate Technology Centre and Network (CTCN), and coordinating many government and non-government participants to develop the full manual. The respondent praises the leaders who coordinated the successful effort.

4.3 Challenges to climate change planning and action

The major challenges that slow the climate change planning and action for agriculture mirror some of the successes. The challenges that emerge frequently, mentioned by more than half of respondents, are (i) insufficient funding; (ii) insufficient information and access to high quality data as well as limited climate information services and knowledge, skills, and capacity to implement adaptation; (iii) insufficient communication and coordination between different stakeholders; (iv) commitment from the national policy level, which has grown substantially but which respondents still identify as a challenge. Figure 8 shows the challenges most frequently reported by survey respondents.

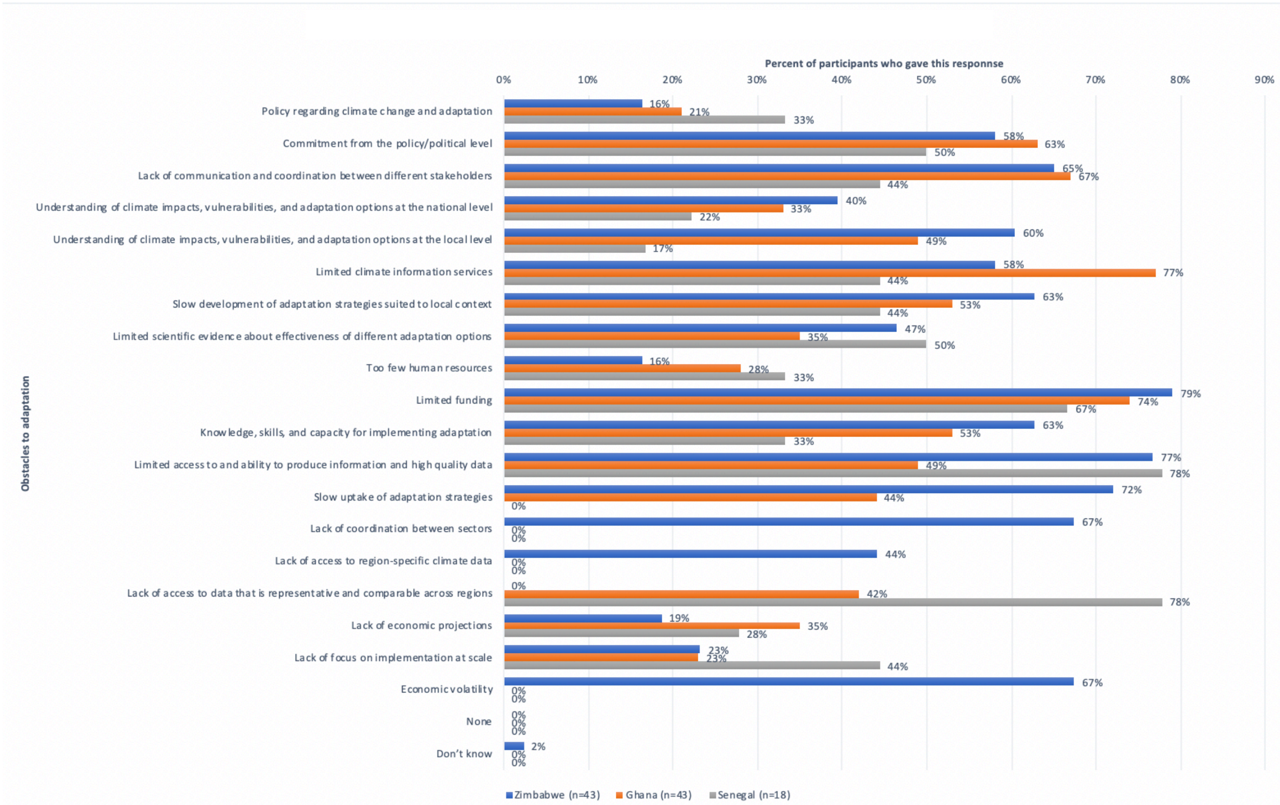

Figure 8. Challenges to progress on climate change planning and action in the agricultural sector
Data are from baseline surveys. Respondents could select multiple responses; therefore percentages of respondents who give each answer do not add up to 100% for each country.

Insufficient coordination between different organizations and efforts is a frequently mentioned obstacle in all three countries, reported by more than half of survey respondents in Ghana and Zimbabwe and in many interviews. Respondents mention that different organizations implement similar efforts at small scales without coordination or learning from each other, and that the lack of cooperation results in waste of resources and failure to increase the scale of initiatives. Conflicts arise over roles and mandates, inhibiting action. Actors do not always have important information. An example of a coordination problem is the promotion of small grains as an adaptation approach in Zimbabwe. Small grains can be more resistant to climate change than is the commonly grown maize, and they provide better nutrition. However, decision makers at national and local levels have focused on production technologies that support maize as a staple food. Small grains were only recently included in input support programs. Even where clear and understandable information has been disseminated, lack of coordination across sectors coupled with insufficient demand result in limited supply of seeds. Insufficient programs to influence food preferences and investment in processing technologies contribute to low demand.

Despite considerable achievements in research, interviewees in all three countries report that insufficient information is an obstacle to progress. More than half of survey respondents mention insufficient knowledge for implementing adaptation, slow development of adaptation strategies suited to the local context, and limited climate information services in Ghana and Zimbabwe, limited understanding of climate impacts, vulnerabilities, and adaptation options at local level in Zimbabwe, and insufficient evidence about effectiveness of adaptation options in Senegal.

Among the main gaps according to interviews and surveys seems to be information needed to plan and implement adaptation strategies that are appropriate for the local context, in which they are implemented. Climate projections and understanding of vulnerabilities and adaptation options remain most often aggregated at broad geographical scales, at which their usefulness for local decisions is limited. Interviewees emphasize that adaptations are implemented at the local level, by local government, private sector, CSOs and farmers, even if they are planned at the national scale. Standardized approaches to adaptation problems are not likely to be effective in all contexts within the country. Effective planning will require differentiating across contexts. Developing appropriately differentiated plans requires information about climatology, climate change, vulnerabilities, and adaptation options that are valid where the adaptations are being implemented.

A related problem is that understanding at the national level of climate-related issues, decisions, and experience at the local level remains limited. Information does not flow effectively from national to local level or vice versa. Therefore, research at the national level and adaptation approaches proposed at the national level do not necessarily address local problems. In addition, experience with adaptation at the local level often does not inform national policy and efforts elsewhere in the country.

Many interviews emphasize need for knowledge, capacity to implement adaptations, and buy-in among farmers and consumers, *who are the main implementers of adaptation strategies*. Limited availability of climate information services that provide tailored services at scales that are relevant to farmers' decisions impedes adaptation. Beyond knowledge, changing producers' and consumers' attitudes to diversify types of grains and developing the necessary value chains both for adaptation to climate change and for improving nutrition remains a challenge.

Understanding of the effectiveness of adaptation strategies in improving livelihoods and the economics of adaptation is insufficient at all scales, national and local. Evidence that shows which adaptation strategies improve livelihood outcomes, for whom, and under what conditions remains scarce. Few studies investigate benefits and costs of adaptation and develop assessments of investments needed to advance adaptation.

Research is not always well connected to the national planning processes. Respondents in Ghana report that interactions between national ministries and universities occur mainly on individual and somewhat ad hoc bases. For example, the University of Ghana (UG) Office of Research formally established the Climate Change Working Group (UG CCWG) in 2013, but there is not yet any connection between the UG CCWG and any ministerial platforms. Also, UG CCWG recently produced two volumes on climate change work in UG and Ghana in general but these works remain largely unknown to the climate change community (Adiku 2019, Cojdoe and

Dovie 2019). Respondents in Ghana report that decision makers are using models and vulnerability assessments that are outdated. In Zimbabwe, vulnerability studies done by a variety of organizations do not use standardized methods and focus on different issues, impeding learning and comparison across districts.

An issue that has received considerable attention but remains problematic is that information is rarely communicated in ways that are well-tailored to any audience, except perhaps researchers. Capacity to understand technical information and time available for interpreting the information differ across decision makers.

Human capacity constrains progress in all three countries. Interviewees report insufficient numbers of staff who are able to downscale regional climate models to produce reliable projections to guide decisions at country or district level. The number of individuals who have data analysis skills is far smaller than is the demand for these skills, especially at sub-national levels. Knowledgeable staff who can implement adaptation strategies well are in short supply at the local level. Respondents in Senegal note that building capacity in local government can be challenging due to frequent turnover of staff. While integrating climate change into the national education curriculum in Zimbabwe was an important achievement, teachers are not trained or equipped to teach this portion of the curriculum. Actors at the local level also lack capacity to access adaptation funding.

Another frequently noted obstacle to progress in all three countries, noted by almost 80% of survey respondents in Senegal and Zimbabwe, is limited access to complete, recent, and high-quality data, and limited capacity to analyze data. Problems with existence of, coverage, and quality concern climate data, data on impacts, and especially agricultural production, and socio-economic data. Countries lack sufficient weather stations, equipment to collect data more generally, and skilled data collection and management staff. Capacity to collect, store, mange, and analyze data is especially lacking at the local level, where most impact and socio-economic data need to be collected. Furthermore, available data is generally too aggregated to be useful for decision-making.

> *"In fact, the climate data that is sometimes disseminated is data that is generally aggregated. When you go to the local scale, the producer may not be able to use this climate data that is given at the national scale to be able to make an appropriate decision when it comes to developing their adaptation strategy."*
> *Interviewee from Senegal*

Even though all three countries have made progress in accessing funding, limited funding is among the top three obstacles to progress on adaptation in the agricultural sector reported by survey respondents in all three countries. A contributing problem is the small number of individuals and/or organizations who have the training and experience needed to compose successful funding proposals. Some funding sources, such as the Green Climate Fund, have proposal requirements that demand prior research, for which capacity is limited.

Respondents in Zimbabwe also mention economic volatility as a significant obstacle to progress. In Ghana, slow development and uptake of technology that is suitable to the local context emerges as a salient issue.

4.4 Channels of influence in national climate change planning processes

Paths of influence that shape national climate change policies are important to understand in order to advance the planning processes. Survey respondents in all three countries were most likely to select national government departments and ministries as being most influential in shaping their work on climate change in the agricultural sector. The second most likely category are international development and technical assistance organizations. The remaining categories were much less likely to be reported. The third most influential category are national research and academic institutions in Ghana, representing 9% of responses and national NGOs in Senegal, which comprise 11% of responses. Figure 9 presents the results.

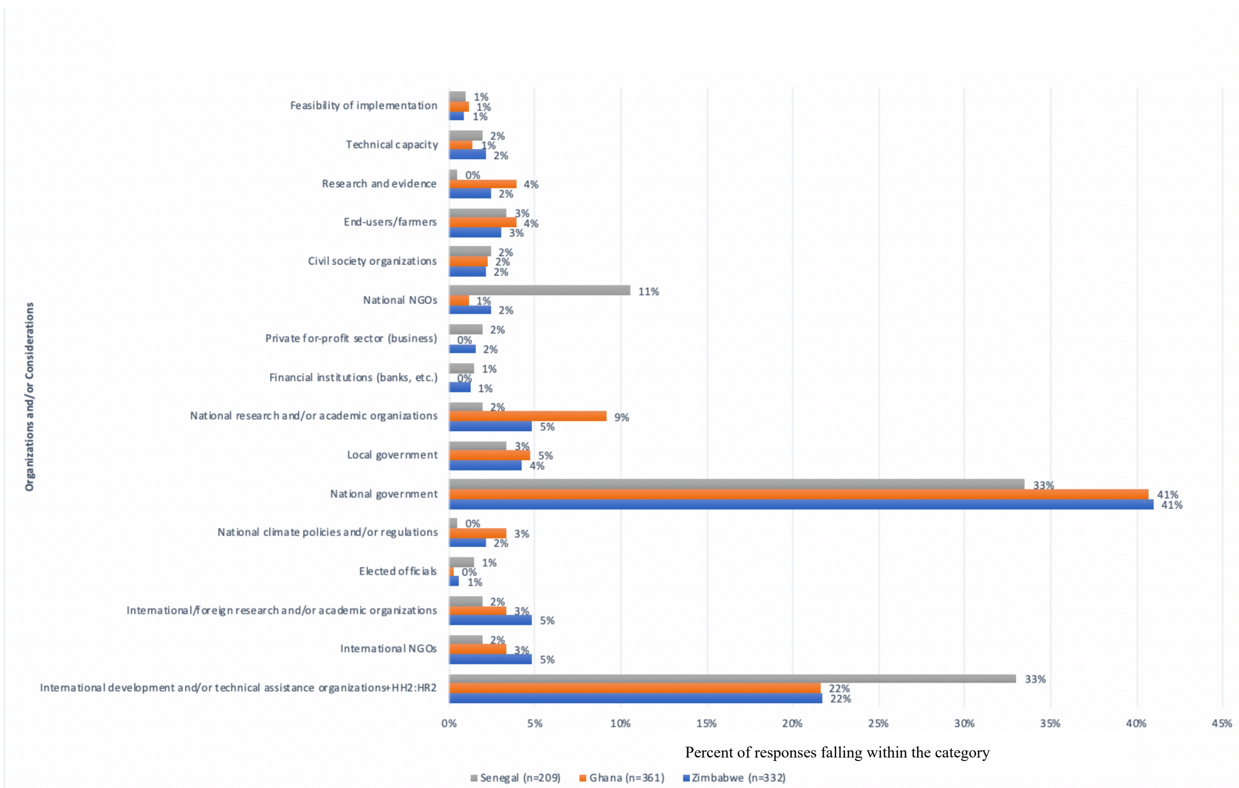

Figure 9. Organizations and considerations that had the most influence on respondent's work on climate change in the agricultural sector

Data are from the baseline surveys. The answer options to survey question include specific organizations as well as general categories, such as "national government" and "national research and/or academic organizations." For the purpose of the figure, we group responses that selected specific organizations under type of organization. Percentage is out of all responses *given, not the number of respondents. The sample size is the number of responses given. The number of respondents is 43 in Ghana and Zimbabwe and 18 in Senegal.*

Ways in which the planning processes are being influenced and can be influenced in the future emerge from interview discussions. Interview respondents addressed questions about: (1) how they have influenced the planning processes; (2) what has influenced their focus on particular vulnerabilities and adaptation approaches in the planning process; and (3) what organizations and factors influence the planning processes and why.

One source of influence is engagement with government ministries who have the mandate to lead national climate change planning. As noted under successes, the commitment and endorsement of the leading ministries has been essential to progress. They have played a central role in developing the planning documents that have focused work on climate change and adaptation in the countries and have helped to secure funding for the work. Government ministries set priorities, develop and approve changes to national policy, develop new regulations, request research that they need to advance their priorities, and provide funding. Interviewees in Zimbabwe explain that ZRBF derives its influence from its close connection to the government. UNDP in Zimbabwe attributes the effectiveness of its projects to a good relationship with the government. National priorities guide its work through ZUNDAF. Interviewees in Ghana and Senegal echo the importance of engaging in national processes to influence planning and action.

> *"So the first thing is really to engage with the various processes that are taking place at national level. So when they convene planning workshops, when they convene stakeholder information dissemination workshops, we have been participating, and also sharing our experiences from the ground, and also even sharing our methodologies for doing certain things."*
> *Interviewee from Zimbabwe*

> *"We [CCASA platform] had to get involved in policies and strategies, I am talking about PRACAS, the policy letters, the program projects that intervene at the Ministry of Agriculture for which we try as much as possible to integrate the climate change dimension. Better in planning we have been involved in the design of INDC and NDC."*
> *Interviewee from Senegal*

National documents are an important vehicle both for engaging with government ministries and for influencing the planning processes. All respondents cite the important role that these documents play in advancing national planning, not only through their content, which focuses attention on particular issues, but equally importantly by forming networks between contributors, which continue to collaborate to achieve multiple objectives, eliciting feedback from different sectors of society, commissioning research, which informs more than the document itself, and drawing funding. Therefore, engagement in formulating the documents is an important channel for influencing the planning processes. Interviewees provide many examples, such as formulating PRACAS being an entry point for research developed by GIZ in Senegal.

> *"Our influence comes from the documents that we have first and foremost, the National Climate Policy and the National Climate Change Response Strategy. The Response Strategy was a consultative document so we believe what is within the strategy reflects what we need to do as a country, is a collective document in our own view since there was wide stakeholder consultation."*
> *Interviewee from Zimbabwe*

Many actors influence the ministries that lead the planning processes, including other government departments, local government, research, civil society, and the private sector. Government ministries themselves reach out to other actors to elicit input. The leading ministries also need to collaborate with others in order to advance the agendas that they coordinate, for example the Climate Change Management Department in Zimbabwe reaches out to provincial and district level to request input and to influence their action on climate in addition to soliciting input from key line ministries and other stakeholders engaged in work on climate change in agriculture, as does the Climate Change Desk in Senegal.

Respondents emphasize that they influence processes most effectively when they collaborate, participate in coalitions, and work through many different channels. Coordination is important in influencing the processes because it allows initiatives to be more effective and use resources more efficiently. Respondents in Zimbabwe report that ZRBF is influential particularly because they bring many actors together from lowest level to national level. ZimVAC is a consortium that coordinates the annual vulnerability assessment in Zimbabwe, and they include many government and non-government organizations who have direct links to programming and implementation.

> *"A very simple first example of the influence we have had is when we set up a working group on climate change. We went to IED-Africa because they had a program in Kaffrine called [Decentralizing Climate Funds] DFC, which supported projects in the Kaffrine region from the Climate Fund. We also knew that in Kaffrine ANACIM was experimenting on how to use climate information as an input value for agricultural decision-making. These two entities interested us because Kaffrine was one of the regions we were working on, and Kaffrine seemed to be a laboratory for climate change and we thought this was a first example of reading complementarity and reading synergy. … So, we thought that before we did anything, we needed to get around the table with even these people [the ones already working in Kaffrine: IED-Africa, ANACIM, FDI-Africa] to find out what they were doing. So, we decided to scale up climate information, to support the [Pluri-disciplinary working group] PWGs as ANACIM was already working on that. We need to know which partners are involved in all of this so that we can complement each other better."*
> *Interviewee from Senegal*

> *"So…. We are going to coordinate very closely with the ZRBF in terms of the districts and the wards where they are working in, so that we make sure that these projects complement each other rather than just doing almost the same things but*

with different people and different times, using different modes in terms of operation."
Interviewee from Zimbabwe

Elected officials at national and local levels may act as channels of information between national government and local levels, influencing the planning processes through the communication of problems and ideas. They can also be influential in creating consensus around issues and in advancing implementation. Often their access to technical expertise is limited, hampering their role. Their influence is also constrained by frequent turnover. Elections replace well-informed and active elected officials with potentially less informed ones.

International agreements, for example UNFCCC, the Paris Agreement, the CTCN, and the IPCC influence the planning process, for example by motivating and providing guidelines for the development of NAPs and NDC, providing informative synthesis reports (in the case of the IPCC) and offering technical assistance (in the case of CTCN), which in turn require research on climate issues. Developing the NAPs and NDC builds understanding of new issues and shapes the course of climate change planning.

The development and technical assistance partners also influence the planning process by investing in and providing technical support for projects. For example, UNDP, GIZ, and FAO support the planning process in Senegal through the SAGA Senegal project, and UNDP through the UNDP GEF-NAPP (National Adaptation Programme of Action to Climate Change) project among others. UNDP, WFP, FAO, CTCN, UNEP, GCF, the World Bank, GEF, IFAD and other players support adaptation in agriculture in Zimbabwe. The support comes in form of asset creation programmes, project development on climate services, small irrigation and other resilience-building programme. The development partners also influence climate action through support for Zimbabwe's participation at the climate negotiations and other related forums such as SARCOF. Furthermore, development partners fund pilot studies and policy making in support of the the government's climate and food related policies. Respondents in Ghana mention the influence of the New Partnership for Africa's Development (NEPAD) scoring criteria. Funding bodies, such as the Green Climate Fund, influence the planning processes through their funding criteria. More generally, research-based evidence is highly valued in funding proposals. Interview respondents also mention that conditions attached to funding proposals have strong influence on the planning and implementation processes.

Universities and researchers play an influential role in climate action through designing and undertaking research whose outputs contribute to understanding of issues and potential solutions as well as serve as vehicles for the formation of partnerships and support applications for funding, as mentioned above. University staff are the core of various climate policy, strategy, and practice document developments as consultants. Research guides adaptation planning by illustrating change in climate conditions that has already occurred, developing climate projections, investigating current and likely future vulnerabilities, and analyzing effectiveness and efficiency of potential adaptation approaches. In Senegal, research in support of PRACAS and PSE, and FAO collaboration on ANACIM's work in Kaffrine influenced national planning, among others. In Ghana, the climate projections developed by the Climate and Space Institute inform policy at the national level. The knowledge products developed by ZRBF and the UNDP 2017 Human Development Report are examples of influential research in Zimbabwe.

> *"… a national adaptation plan cannot be done without a reading of the vulnerabilities. This is not possible. Adaptation responds to a sensitivity-impact-vulnerability scheme. If you don't have it, you won't have that reading."*
> *Interviewee from Senegal*

> *"When we started, there was not much info in Zimbabwe on climate change. So we commissioned four research projects to inform. And we also did some case studies … to kind of inform the government of Zimbabwe on the current status of climate change impacts, vulnerabilities and what could it entail when it comes to strategies. So through that project we recommended a lot of things including the National Climate Change Response Strategy, the Climate Change Act; the National Climate Change Policy ... And... yeah there's the strategy, the policy and the bill which is coming on now."*
> *Interviewee from Zimbabwe*

Local government, civil society, and communities influence the climate change planning and action processes because adaptation plans are implemented at the local level and implementing adaptation in agriculture depends on cooperation and buy-in from local government, communities, and farmers as well as on the capacity of these actors. The local level also provides information to the national level about problems that need to be addressed and potentially experience with approaches that worked or did not work that can guide adaptation efforts elsewhere. Local customs can influence national policy. As a respondent in Senegal notes "CNCR guides government decisions … because the agro-sylvo-pastoral law is really a major contribution from the peasant world. This is the very basis of many policies and even the PSE is supported by this law." Voices from the local level are not necessarily as influential as they should be, according to many interviewees. Respondents from all three countries report that adaptation approaches proposed at the national level do not necessarily address local problems or reflect what has been learned at the local level, and the flow of information between local and national levels is limited. However, evidence based on testing adaptation approaches in local contexts has the potential to be highly influential.

> *"Experimentation at the local level with all the actors, arriving at a result, capitalizing on this result, developing political dialogue at the national level, identifying the national planning framework and influencing at this level: this is the scheme we experimented to influence the national planning process."*
> *Interviewee from Senegal*

> *"I think even just sharing some of our experiences in terms of implementing adaptation projects on the ground we have found that as a way also for influencing the process because you really want to make sure the adaptation plans that eventually we come up with at national level they should be knowledge-based. And I think it's quite good if they are informed by practice."*
> *Interviewee from Zimbabwe*

Interviews mention the private sector least often as a source of influence on the national climate change planning and action processes in agriculture except in Senegal. In Senegal, several well-organized agricultural industry groups such as the peanut, dairy, and meat producers represented by CNCR, National Interprofessional Peanut Committee (CNIA), SONACOS. and cattle breeders seem to engage with the adaptation planning process. Also, The National Agency for Agricultural and Rural Advice (ANCAR) brings together professionals from entire supply chains. Several respondents in Ghana and Zimbabwe mention that the private sector is not yet having much influence.

> *"… the private sector involvement in adaptation in Ghana is also entirely missing. So, some of the work, now we have developed a strategy for engaging private sector in climate change adaptation, it's yet to be published …"*
> *Interviewee from Ghana*

5. Sources of information and their roles in national climate change planning

5.1 Information that stakeholders are using and how they are using it

The discussion of successes in national climate change planning and action in agriculture and obstacles to further progress illustrates that research and information play a critical role in the planning processes and in implementation. In the words of one of the respondents, one "… can't manage risk based on perception." While information is not sufficient for progress, it is necessary for establishing what are the problems that need to be addressed and what are potential solutions.

Interviewees emphasize that two kinds of information are critical to the planning processes. (1) One is scientific information. Vulnerability assessments are critical for diagnosing what adaptation approaches need to address, and assessments of adaptation strategies are a useful guide for policy and investment decisions. (2) The second are the national documents that present priorities established by the leading ministries. Work on climate change issues is more likely to advance if it is consistent with national policy. Some interviewees add that understanding what information policy makers find credible and what convinces them is useful in shaping how to communicate information.

Information that is most useful depends on the user and the purpose for which they need information. Researchers and analysts may need raw data, and some can use or adapt models developed elsewhere to respond to specific research questions. The capacity to use data and models is concentrated in academia, research organizations, and government departments that conduct their own research. The technical capacity of staff in the national governments varies. Respondents from Senegal as well as the AgMIP project team in Senegal report that the government ministries that lead the climate change planning have strong technical capacity and conduct research. The leading ministries in Zimbabwe appear to rely on technical reports and scientific articles produced outside the government[1]. The skills to conduct research appear to be rare in government below the national level.

The main sources of information, on which survey respondents report relying, are national government departments and ministries and international development and technical assistance organizations. Respondents provided specific organizations in response to the question. The great majority of organizations mentioned fall in these two categories. Figure 10 presents the results. The sources of information that were reported as the most trusted sources also are overwhelmingly in these two categories. The results are very similar to Figure 10, and we show them in Figure A.1 in Appendix A.1. The remaining categories are much less likely to be reported, with international and foreign research and academic institutions being in third place in Zimbabwe and Senegal, and national research and academic institutions in Ghana.

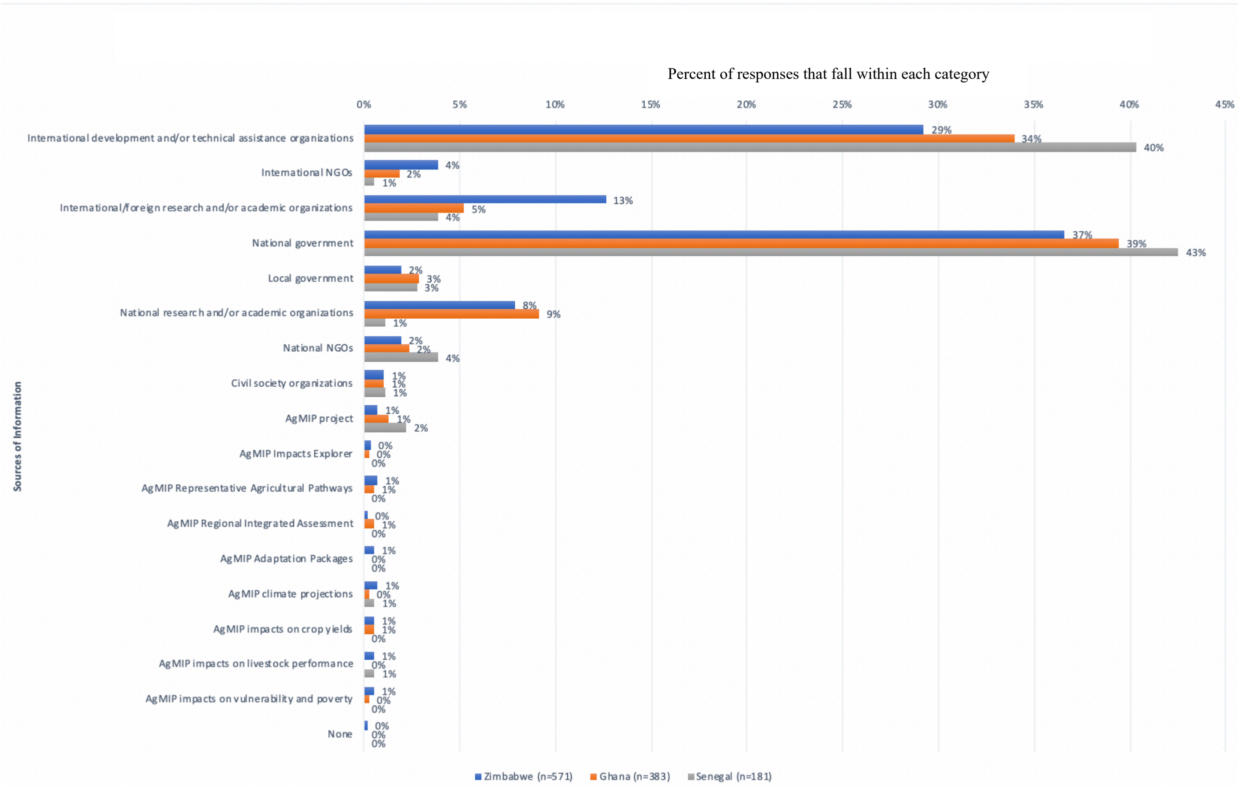

Figure 10. Sources of information used by respondents in climate change work in agriculture in last three years
Data are from baseline surveys. The answer options to survey question include specific organizations as well as general categories, such as "national government" and "national research and/or academic organizations." For the purpose of the figure, we group responses that selected specific organizations under type of organization. Percentage is out of all responses

[1] For example, in Zimbabwe, documentation of climate change includes erratic rainfall patterns and decreasing seasonal rainfall punctuated by sortening season length (Moyo 2020), increasing extreme events (Moyo and Nangombe 2015) and projected divergent climate scenarios (Moyo et al. 2018). Documentation of national planning processes include Jakarazi et al. 2017, Moyo 2017, Moyo 2018, and Brazier 2017.

given, not the number of respondents. The sample size is the number of responses given. The number of respondents is 43 in Ghana and Zimbabwe and 18 in Senegal.

Interviews discuss how decision makers, policy makers, and planners rely on existing information or analysis of existing information to make decisions, develop planning documents, prepare national reports, advise, develop adaptations at local level, communicate information, advocate, and stay informed about developments in the country and elsewhere in the world. These individuals use publications, scientific articles, commissioned research, technical reports, monitoring and evaluation reports, policy analysis, and policy and planning documents. According to interviews, the ability to use scientific information presented in scientific language is generally low below the national level and outside research departments and academia even at the national level, except possibly in the leading national ministries in Senegal.

Examples of how the national planning process has used information in Senegal include climate projections developed by ANACIM for four zones of the country and a number of projects that have assessed vulnerability to climate in different parts of the country, such as SAGA Senegal, PAS-PNA, research in support of PRACAS, and research in the Fatick region and in Kaffrine. A respondent reports the importance of research that informed efforts to eradicate locusts before the start of the rainy season.

Ghana Climate and Space Institute uses data from the Ghana Meteorological Agency to develop information that is relevant to decisions, especially for farmers. The information includes seasonal forecasts and climatological information, such as the longest dry period that farmers should expect during a season, to help farmers manage risks.

Interviewees in Zimbabwe report that data and models from the Climate Systems Analysis Group at the University of Capetown have been very useful for producing downscaled climate change projections and seasonal forecasts for Zimbabwe, including information about onset and cessation of rains. Respondents have used the data to drive crop impact models. Others report using information from the World Bank Climate Wizard Portal to understand likely future climate in different parts of Zimbabwe. Respondents have found that the Climate Wizard Portal is especially useful for communicating easy to understand information to less sophisticated audiences. ZimVAC produces information about vulnerability and areas where crises are occurring that is useful for guiding adaptation decisions. A NGO, Practical Action, disseminates useful information about CSA.

Respondents in Zimbabwe report that information produced by AgMIP for the district of Nkayi has been tremendously useful for planning in Nkayi. Respondents have used the information to argue how climate change is affecting communities in Nkayi. Residents in the district were using moisture conservation strategies developed in conjunction with the AgMIP research and were well-informed about the reasons for using those strategies. The information has also helped to plan cropping programs and livestock production by showing that the growing season has become shorter by 15 to 30 days and documenting variation in rainfall between seasons. The results supported further research on producing adequate biomass to feed livestock. The implications have been used in Nkayi. The work on biomass to feed livestock during dry seasons has been replicated in other districts. Other districts have also adopted lessons from Nkayi about crop mixes.

Respondents note that the AgMIP research on Nkayi was difficult to use at the national level because it was specific to a district. The recommendation that emerges is that similar research is needed in other districts that together would cover representative regions of Zimbabwe, since conditions and solutions are likely to vary across regions.

Respondents note the importance of understanding indigenous knowledge and incorporating it into research and planning where appropriate. A number of respondents gather their own local information through surveys of farmers or interaction with local organizations. Local government technical departments are sources of local information. Another important means of two-way communication with the local level is community radio.

5.1.1 Awareness of AgMIP information products

About a third of the survey respondents in Ghana, a quarter of the survey respondents in Senegal, and less than a third in Zimbabwe had heard of AgMIP before the CLARE A-team project began. Among the seven respondents in Ghana and in Zimbabwe and one respondent in Senegal who had used AgMIP information in their work, most used research on climate impacts on crop yields and Representative Agricultural Pathways.

5.2 The limitations of existing information

Most decision makers rely on information produced and reported by others. Therefore, the usefulness of information depends on existence of (1) information that addresses the decision maker’s problem in a way that is relevant to the decision maker’s context and timeframe; (2) information presented in a way that the decision maker can understand; (3) information that is available when the decision has to be made. Available information rarely satisfies any one of these three conditions and even more rarely satisfies all three.

In all three countries, information that is not specific to the respondent’s needs is among the most often listed obstacles to using existing information for the respondents’ work in the agricultural sector. Another commonly mentioned obstacle is insufficient quantitative information about adaptation at local scale. Other top obstacles include access to timely data and information in Ghana and Zimbabwe, quality of agricultural impact data and inadequate data for downscaling weather forecasts in Ghana, quality of climate and weather data in Zimbabwe, and information not available when it is needed in Senegal. Figure 11 presents the results for obstacles that were common across countries, as most were. Figures in Appendix A.2 show obstacles in each country, which include several obstacles that are specific to each country.

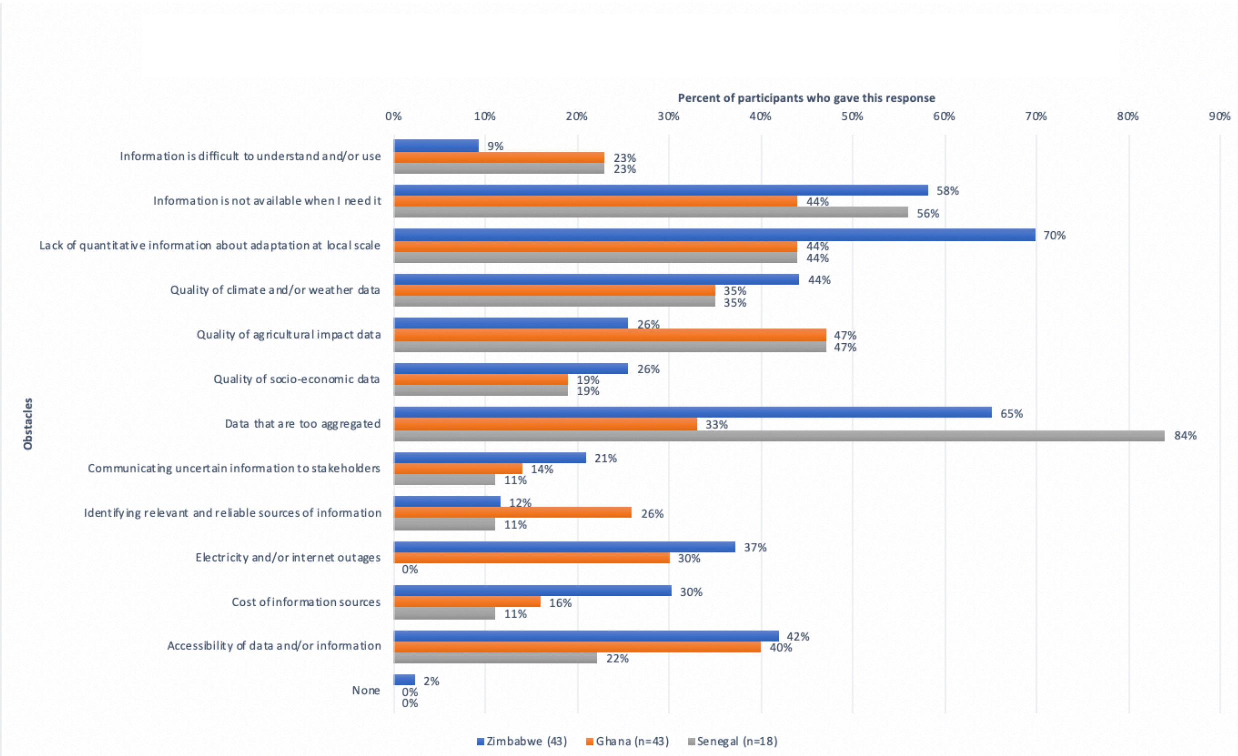

Figure 11. Obstacles that impede use of existing information for respondents' work on climate change in the agricultural sector
Data are from baseline surveys. Respondents could select multiple responses; therefore percentages of respondents who give each answer do not add up to 100% for each country.

A limitation of existing information that arises most frequently in the interviews, as in the surveys, is that available information, whether data or analyses, are either too aggregated at global or regional (supra-national) levels or, much less often, they are specific to a particular locality without guidance as to where else the information may apply. In many interviews, this limitation of available information applies to models of climate and/or climate impacts. Interviewees report that model output is too coarse to be useful for decision making. The same point applies to a variety of data, including data on agricultural production and socio-economic outcomes, information about vulnerability, and analyses of adaptation strategies. Use of aggregated information to guide local decisions results in big uncertainty for decision makers.

> *"…if we have, for example, a global temperature increase of 1.5 ℃, what would happen in Senegal? And better still, how could each region of Senegal suffer from this global increase because we know that even at the local level, realities already show us that the regions do not have the same specificities, so a global increase in temperature must affect the different regions differently."*
> *Interviewee from Senegal*

"We would have loved for the information to be maybe from five to six districts that would say these are kind of representative of the different sort of regions that we have in the country. Then we would be able to use the information."
Interviewee from Zimbabwe

"I think if information can be drawn to be area-specific rather than just generalize and say maybe in this province the situation is like this. At times you come up with recommendations of interventions which might not really be that specifically addressing challenge in a certain community. So if information could be that specific in a specific area or jurisdiction, I think it can also inform us in terms of which programs or what kind of interventions can we come out than just to blanket or generalize with like in this province issue is like this, in this province information is like this."
Interviewee from Zimbabwe

The need emerges from the interviews for data and analyses, from climate projections through vulnerability to adaptation, that provides guidance for specific decision problems in well-defined contexts. Information would be most useful if it includes a clear description of the kinds of decisions to which it applies and environmental and socio-economic conditions under which it applies. Ideally, the information would also include an assessment of uncertainty and analyses of how that uncertainty may affect decision outcomes. Respondents in Ghana and Zimbabwe emphasize insufficient vulnerability assessments that can guide the next steps in adaptation planning.

A related issue is that information should be tailored to user types. Different decision makers have different needs and capacities for using information. Some can develop models and/or use existing models as long as those models are sufficiently well documented. Some can analyze raw data. The more decision makers are involved with implementation of risk management and adaptation strategies on the ground, the less they tend to have the capacity to do either of the above. Decision makers who are more involved in implementation need information that is well developed for their information problems with clear guidance on how to apply it. Ministers and elected officials at the national level, on the other hand, need brief communication of main points relevant to policies on which they are working or describing problems that they should address.

"... we need to make sure that the information or the knowledge is packaged in information-- in formats-- which can be accessible or usable by different types of stakeholders, especially focusing on farmers. It would really be very great if you could focus on information that could be used by farmers."
Interviewee from Zimbabwe

Another theme that emerges in the interviews is the scarcity of evidence regarding what adaptation approaches work well, for whom, and under what conditions and how do the benefits compare to costs. Decisions about adaptation would benefit from understanding the impacts that different approaches to adaptation have on agricultural production and livelihoods at farm level and how those impacts differ across contexts. The approaches to adaptation include providing climate information services. What types of climate information services improve production and livelihoods, for whom, and under what conditions? Benefit-cost analyses would provide useful guidance for investing in different approaches.

> *"... when you're going to be implementing the national adaptation plan, when we eventually come up with the plan, one of the things that we are looking at within that... that national adaptation plan is for us to have some kind of a network that will provide the data and some kind of database related to climate change adaptation, that would be kind of systematic, in certain or limited kind of parameters that enable us to actually see whether we are adapting, building resilience to or reducing vulnerability in agriculture. So for now we have bits and pieces of information from... from everywhere, but the adaptation planning process is going to come up with some kind of systematic way of collecting these data and some kind of indicators that will allow us to see that we are making progress or not."*
> *Interviewee from Zimbabwe*

> *"But also you might be thinking about the cost benefit analysis, ..., I think these are some of those things that you want to also look at as you make recommendations for farmers in a particular area, because at times, you know, you just end with the recommendation that this works without going a step further to look at the economics of what you're recommending."*
> *Interviewee from Zimbabwe*

Interviewees emphasize the lack of information that is useful to farmers. Farmers need information that is simple, very precise, and well-suited to their farms. Part of the gap is absence of well-developed climate information services. Farmers need information about how the climate in which they work is changing, as well as weather and seasonal forecasts conveyed in a way that can inform their farm management decisions: planting, application of inputs, management of soil, harvest, and others. Examples of useful information include when growing season will start, when it will end, how many days of rain can the farmer expect, how much it will rain on those days, length and timing of dry periods, etc. Respondents in Senegal note limited availability of informative climate forecasts, including weather forecasts. The information should include guidance on how uncertainty may affect decision outcomes.

> *"I would say we need to understand the perceptions of the end – users, of the farmers, the key actors within the agricultural value chain and what really drives their decision making and their preferences. We need to have a good understanding of that. That would help us in shaping our policy and where there is the need to even change mind-set then we would drive in that direction."*
> *Interviewee from Ghana*

> *"We talk all the time about the early warning system. I think it's time to set up a national system that can inform farmers in real time about the climate, the rainy season and accompany them in their campaign so that they can sow and harvest in time to avoid some of the setbacks they have experienced in the past."*
> *Interviewee from Senegal*

Furthermore, interviewees note that more information would be beneficial about adaptation approaches that farmers are implementing. Information about effectiveness of adaptation approaches undertaken in local communities is rarely available and could inform testing and scaling up of approaches in those communities and in other districts.

> *"I think that we still have a lot to learn from our traditional farming practices that we need to properly study and look at how we can upscale it or improve those practices, leveraging on technology and knowledge, new knowledge that we have so that even for commercial scale farming, some of these practices may be well suited and adapted."*
> *Interviewee from Ghana*

Many interviewees mention that access to data is inadequate. They often cannot obtain data that they need, or the data are incomplete, of poor quality, or not available in accessible formats. The comments apply to climate data, data on agricultural production, and data on socio-economic outcomes. The data, especially climate data, may also be costly. A particularly big gap exists at the local level. Data that document the situation at fine scales in specific locations are rarely available. Interviewees discuss the need to improve human and physical resources for collecting, storing, and managing data at the local level. The need includes more thorough coverage of monitoring of environmental conditions, agricultural production, and socio-economic outcomes across each country.

> *"For what percentage? Where exactly? What kind of degradation? … So, when I speak just now about preserving the productive base, this preservation can be better ensured if we have a good mastery of the evolution of the situation. We can say, for example, that in a reference situation we have 40,000 ha that disappear every year and that we can monitor this and work to regress this data over time."*
> *Interviewee from Senegal*

Two other related obstacles to using existing information are the difficulty in assessing what information is credible and reliable, and finding such information. Interviewees use multiple sources in order to triangulate information. They rely more heavily on information from trusted sources, such as international organizations, national government, and prestigious academic centers. However, information from such sources tends to be more aggregated and less tailored to specific contexts, in which decisions are being made. Reports from studies carried out in local contexts often remain unpublished and difficult to find and/or it is difficult to assess their credibility. Furthermore, information tends to be dispersed across a variety of sources. Platforms that collect information that is known to be reliable and organized by topic, including information that is relevant to specific contexts in the country, would be tremendously valuable.

Interviewees also mention the need for more democratic sharing of information. Access to newest research is limited for those who are not in academia and even subscriptions to older journals can be expensive. Decision-makers who are not within an institution that produces information may not be permitted to use that information. These factors combine with insufficient updating of information to limit access to up-to-date information.

Respondents in Ghana and Zimbabwe particularly note that poor internet access limits ability to access data and information.

6. Research opportunities and potential role for AgMIP

6.1 Research opportunities

The primary research opportunities that emerge from the survey and interviews parallel the main limitations of existing information. The survey asked respondents about needs for new information and research priorities. The most frequent request for information in all three countries is information that is specific to an area in order to inform decisions that are appropriate for local conditions. The second most frequent request in two of the countries and among top three in all countries is a request for assessments of adaptation strategies. Interviews similarly suggested that decision makers did not have sufficient information and evidence of effectiveness to identify appropriate adaptation strategies even if they had the will and the means to advance adaptation. An additional request for more disaggregated information is for finer resolution of climate projections and weather information, especially in Senegal and Zimbabwe. Figure 12 shows requests for information that were common across the three countries. Some requests differed across countries, and we show requests for information by country in Appendix A.3.

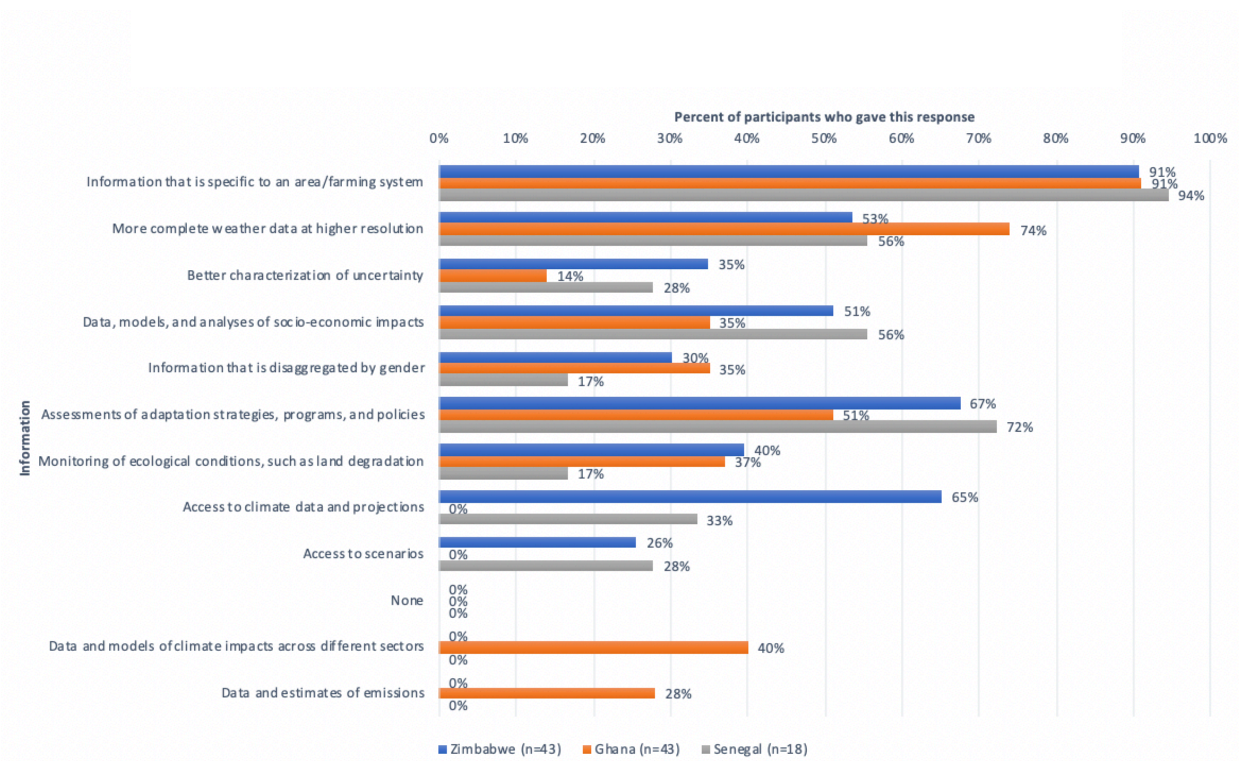

Figure 12. Needs for information to support climate change work in agriculture
Data are from baseline surveys. Respondents could select multiple responses; therefore percentages of respondents who give each answer do not add up to 100% for each country.

Two research priorities are among those listed by most respondents in each country: carrying out impact, vulnerability, and adaptation analyses for all representative regions and agro-ecological zones; and assessment of adaptation options. Both of these parallel the two most frequent requests for information. The former identifies the need for research that provides information that is specific to local conditions. The latter is a request for better evidence regarding effective adaptation approaches under different environmental and socio-economic conditions. Additional priorities include research that supports the development of capacity to adapt among farmers and extension services in all three countries, research to support the development of climate information services in Ghana and Zimbabwe, integrating indigenous knowledge in research in Ghana and Senegal; downscaling climate projections to the local level in Ghana and Zimbabwe; and climate smart technologies and practices in Ghana. In Appendix A.4 Figures A.8, A.9, and A.10, we show research priorities identified by survey respondents in each country.

The primary research opportunity that emerges from the interviews parallels the survey results. Responses suggest that new research should provide information that is relevant to specific decision problems and is relevant to the contexts in which those decisions are being made. Every location does not require different information. Research could assess what are representative regions of the country, defining under which environmental and socio-economic conditions specific components of information differ and decision-makers should receive different guidance. The request applies to climate projections, analysis of current vulnerabilities and models of future vulnerabilities, and analysis of adaptation options.

> *"… we only conducted the study in one region, is that it should be extended to the whole of Senegal and, if possible, we should have the same approach and methodology, which will make it possible to synthesize all the results from the eco-geographical regions of Senegal and give an overall vision of the vulnerability of agriculture in Senegal in general, and then make recommendations for each region of Senegal."*
> *Interviewee from Senegal*

> *"I think the idea of scaling up and seeing whether we can draw different lessons from different parts of the country I think will be very useful."*
> *Interviewee from Zimbabwe*

Representative regions may not be contiguous and may differ for different decisions. For example, vulnerabilities and benefit cost analyses of adaptations may differ within a particular climatic and/or agro-ecological region according to whether a location is urban or rural, by average income or income distribution, by farm size, by existence of institutions such as insurance, by aspects of governance, and other factors. A decision maker should be able to find guidance for different types of decision based on the characteristics of different parts of their region.

The second area of opportunity that receives particular emphasis in interviews is the need to understand the benefits and costs of adaptation options. Net benefits are composed of the positive and negative impacts of an adaptation approach on agricultural production and livelihoods. The net benefits of adaptation approaches are likely to vary under different environmental and socio-economic conditions. Understanding that variance enables decision-makers to design approaches for their particular conditions. A benefit cost analysis compares net benefits to costs to assess what investment should be made in a particular approach.

Effectiveness of adaptation approaches needs to be studied at the local level. Empirical studies of impacts of adaptation approaches produce evidence that can be used to develop models that may predict the impacts of adaptation approaches under future conditions. Most current models of adaptation impacts omit the behavioral component that determines who adopts the adaptation behavior, how the behavior disseminates in the population from the initial adopters, how agents implement the adaptation, and how the adaptation affects other parts of the economic system.[2] The behavioral component is essential for predicting impacts, and its development requires empirical estimation of impacts.

Many interviewees express the need for locally-based empirical research. Respondents mention that research on vulnerability and especially on adaptation needs to test adaptations in communities, learn from what communities are already doing, and provide evidence that can guide the transfer to other areas and scaling up of effective approaches within the study area and elsewhere. Many repeat that adaptation planning should be based on evidence and that existing evidence is inadequate. Some interviewees suggest that the research should be participatory. Effectively organizing research around the main decision problems requires involving the decision makers to understand the decision makers' objectives, capacities, and constraints and the nature of the decision problem. Furthermore, adaptation requires farmers and other decision makers to adopt new practices. Understanding what practices can be acceptable to decision makers and what interventions can help decision makers to accept new practices requires locally-based research and involvement by the decision makers.

> *"I think there is a lot of action-research to be done at this level: helping communities adapt to climate change. But don't just do studies and leave; you have to experiment with a whole village to see the results on the field. What we often see is project-based research; a team comes, does research for a project and leaves. As long as we continue like this, we will never be able to deal with climate change with our farmers and others."*
> *Interviewee from Senegal*

> *"… this should not be work exclusively centered within the four walls of a laboratory, but we should go towards the communities, exchange with them, take their concerns into account and try to integrate them into these models."*
> *Interviewee from Senegal*

> *"[Climate change adaptation and impact assessments] should be more localized and participatory…. It shouldn't be prescriptive."*
> *Interviewee from Zimbabwe*

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[2] Aerts et al 2018 make a similar point in the context of flood risk assessment.

"It must start from the needs of the actors in the field, the technical services, policies and so on. Start from there to understand the actors' problems. From there, the research themes will be proposed nationally and validated by the Ministry or the different stakeholders."
Interviewee from Senegal

"I think there's a lot of knowledge gaps when it comes to adaptation strategies or options for agriculture. And I think the NAP process would actually want to be as knowledge-based as possible. So I think that's really a very clear low-hanging fruit for AgMIP."
Interviewee from Zimbabwe

Respondents from Senegal report that they shared information developed by AgMIP in Nioro with farmers. They would have liked to see follow-up research that would analyze the impacts that the information had on outcomes in the region.

A number of interview respondents, especially in Ghana and Senegal, mention that new research should address the need to develop national climate information services. The focus on change in rainfall patterns and unpredictable rainfall as hazards that are at the heart of the impacts of climate change on agriculture supports the importance climate information services. Respondents discuss that climate information services could help make long-term plans as well as guide short-term weekly and even daily activities on the farm and in other parts of the agricultural system. The establishment of effective climate information services requires improved capacity to provide reliable seasonal and weather forecasts. Equally importantly, it depends on effective collaboration mechanisms that focus the development of information on variables that are useful for making decisions and that translate climate information into implications for decisions, including the effects of uncertainty. Climate information services are one potential climate adaptation strategy. Their effectiveness requires research on impacts on users' livelihoods under different conditions and implications for appropriate design.

A number of interview respondents mention that adaptation planning rarely adopts a systems perspective. Planners should consider what approaches can be effective given influences that sectors exert on each other's vulnerability and performance. Interviews discuss that AgMIP is uniquely positioned to analyze vulnerability and adaptation in a framework that integrates the roles of different sectors, for example agriculture, water, energy as well as dimensions such as the physical, social, and economic environments, and different functions such provision of information, production of adapted seeds, improvement of soil quality, the entire length of the value chains, etc. Interviewees report that integrated analyses are scarce but very helpful for decision making when they exist.

Interviewees emphasize especially the insufficiency of existing analyses of the socio-economic dimensions of vulnerability and adaptation. Interviewees in all three countries discuss that adaptation planning requires better understanding of the economics of adaptation: what is the distribution of benefits and the distribution of costs of adaptation in the population. Understanding the economics is critical for prioritizing adaptation investments. Respondents, especially in Zimbabwe, recommend more research on differences in vulnerability and adaptation between different social groups, such as different genders and ages, also integrating the issue of migration.

Interviews mention that updating research over time is an important gap, especially updating vulnerability studies. Respondents in Ghana discuss the benefits of visioning scenarios that explore potential futures.

Several other research topics in which interviewees express interest include water conservation; CSA technologies and practices; index insurance; seeds that are adapted to the changing climate, including shorter growing seasons; seeds with greater nutritional content and more nutritional diversity; and adapted livestock breeds.

> *"It's the soil productivity; for us it's extremely important. It is important to define the types of seed according to the given time, according to climate change, to say that such and such a seed with such and such a soil, to make an exact soil analysis, an exact scientific cartography that will allow us to have productivity instead of saying every year we need fertilizers and we need amendments, we need such and such a thing for the soil to be productive."*
> *Interviewee from Senegal*

Interviewees mention that creating a baseline in the country against which future progress on adaptation could be compared would be very useful.

6.2 How should AgMIP engage to be effective

Interviewees see an opportunity for AgMIP to strengthen the integration of climate change into national planning. Many say that the time is right for such an engagement because the planning processes began recently, they are still taking shape, but at the same time they are institutionalized and have gained traction in all three countries. Therefore, inputs can shape how the processes mature. It is important for AgMIP to engage closely with the national ministries who are leading the climate change planning and action efforts and to participate in existing processes such as the development of the NDCs. It is also important to participate and provide input into the development of national documents. The documents are time and resource-consuming to produce, and the ministries do not update them often. The time when the documents are being developed is a rare opportunity. The documents play an important role in shaping the future dialogue, planning, and action in the country.

> *"What AgMIP is doing is important. But it needs to be more popular, better known, and it needs to be part of the planning process of ministries, especially the Ministry of Agriculture, and they need to be really involved and take ownership of it. They need to see it as a source to inform their decision-making."*
> *Interviewee from Senegal*

> *"We need the input the AgMIP project into the national adaptation planning process, so that once we are through crafting the document, so your interventions will be timely to inform the document. You know when we come up with these*

national documents it takes a very long time to revise them so the best time to influence is now through the statistics that you have."
Interviewee from Zimbabwe

"Currently, national planning has integrated climate change into the process. And this was only put in place last year and today we are in a test phase of this process. In this sense, I see this as an opportunity for AgMIP to be able to strengthen this dynamic."
Interviewee from Senegal

Another point that emerges from the interviews is that AgMIP should engage with a broad set of stakeholders from the beginning of each phase of research, in a continuous and iterative way. The research and information produced will be more useful if decision makers provide input into research questions and even into the process, since a research team may not frame research to address problems that are relevant to decision making in the country without early and continuous input from decision makers. Involvement in discussion platforms and with stakeholders helps to understand:

- What are national priorities
- What are problems and experiences at local level
- What has been tried and to what effect
- What questions do decision makers have
- What information can decision makers understand and use
- Clarify and triangulate questions and information across different networks

The broader the engagement, the more likely the output is to be useful. Involving stakeholders at the local level, even farmers, is especially valuable. It is also important to engage across different levels on each problem so that, for example feedback from farmers and from local government can inform the same issue and result in adaptation efforts that are more likely to be supported by both and therefore implemented.

"For example, share with them the development of the research protocol as well as the collection of data and the first results obtained. Do not wait until the end of the studies and organize a sharing workshop…"
Interviewee from Senegal

"I think that's also why it's good to be in discussion forums and in discussion exchanges to allow you to share your questions, to ask for clarification with other networks; and it allows you to validate the information received as being good or being quite precise or not."
Interviewee from Senegal

Similarly, AgMIP should engage with academia and research organizations in each country and with other projects that are working on climate change in order to expand the work being done in a collaborative way. The research should complement existing efforts and develop synergies.

Finally, AgMIP should communicate the knowledge that is developed widely and in ways that are appropriate for different types of stakeholders, including extension officers and farmers.

Results should be available in different formats that are suitable for different decision makers, such as reports, visualizations, online information such as the Impacts Explorer, etc.

> *"It's almost at the final stages, but one of the things which I see very lacking in that strategy is because, when it comes to learning we need to make sure that the information or the knowledge is packaged in information-- in formats--which can be accessible or usable by different types of stakeholders, especially focusing on farmers. It would really be very great if you could focus on information that could be used by farmers."*
> *Interviewee from Zimbabwe*

7. Impacts of the COVID – 19 pandemic on national climate change planning for agriculture

The team conducted the entire CLARE A-team project and the baseline study during the COVID-19 pandemic. The pandemic is likely to have affected climate change planning in the three countries, as well as data collection for this study as discussed in Section 2. The effect of the pandemic that about 90% of survey respondents in Ghana and Zimbabwe report and about 60% of respondents in Senegal is difficulty in communicating with stakeholders especially at the local level and especially with farmers, and difficulty in collecting information at the local level. Therefore, the pandemic is further impeding communication between national and local levels, which the interviews had already cited as an obstacle to adaptation and a reason why national policy does not necessarily address needs at the local level.

The next most frequently mentioned effects of the pandemic in the survey are a diversion of resources to fight the pandemic mentioned by almost half the respondents in Ghana and Senegal and almost a third in Zimbabwe. About a third of the respondents in Ghana and Senegal and half the respondents in Zimbabwe report a slowing down of climate change planning and related work. Internet access is particularly problematic in Zimbabwe, and interviews confirm that communication became particularly difficult during the pandemic in Zimbabwe, while in Senegal some interviewees report that the pandemic revealed that they could have effective virtual meetings, which saved funds otherwise devoted to expensive travel. However, even in Senegal ability to work virtually depends on location as access to internet is poor or non-existent in more remote areas. On the more positive side, almost half the survey respondents in Ghana and just over a third in Senegal and Zimbabwe say that the pandemic spurred thinking about innovative approaches to improving resilience to risks, especially with respect to ways of communicating.

The pandemic has also affected adaptation to climate change by depressing livelihoods. The greatest number of survey respondents in all three countries report in response to an open-ended question that the pandemic has disrupted livelihoods mainly because the closures and limits on mobility that are designed to contain the pandemic have impeded the transport and sale of food and other goods and have closed markets, leading to reduced incomes and job losses. A smaller number of respondents mention a decline in food security in Senegal and in Zimbabwe. On a scale of 1 (no effects) to 7 (severe effects), respondents in Zimbabwe rank the effects of the pandemic on availability and affordability of food as more severe than in the other two countries. The average ranking of effects on availability is about 3.5 in Ghana, 4 in Senegal, and 5 in Zimbabwe, while the ranking of the effect on affordability is just under 5 in Ghana and Senegal and almost 6 in Zimbabwe. Prices of food have risen during the pandemic because of disruptions of supply due to limited mobility and market closures. Price increases have combined with income losses to erode affordability of food and therefore also attention to and spending on other needs.

8. Conclusions

The study finds that climate change planning for the agricultural sector is proceeding at the national level, and there have been important achievements in all three countries. The process is in relatively early stages though it began earliest and is most advanced in Senegal. A number of challenges remain in each country. The responsibility for climate change planning for agriculture rests in a clearly identified national ministry in each country. However, the leading ministry requires many partners to advance the complex process, and responsibilities overlap among those partners leading to inadequate coordination, duplication of efforts as well as omissions, and sometimes conflict. All three countries have conducted vulnerability studies of the agricultural sector and have developed national planning and policy documents. However, some respondents indicate that the vulnerability studies have become outdated, and that they provide information that is too aggregated and not sufficiently specific to local conditions in different regions of the country. Similarly, the development of national policy is insufficiently informed by local needs and conditions in different regions.

The obstacles to national climate change planning and to adaptation suggest the need for reforms at the level of institutions, the planning process, and resource allocation as well needs for knowledge and information. The following sections present implications for policy, research, and engagement.

Policy implications

- A prevalent theme in all three countries is lack of knowledge and capacity at the local level, where adaptations are implemented. There is a need for building knowledge about climate change, vulnerabilities, and adaptation among local government staff, civil society organizations, and farmers, allocating resources to the local level, and improving capacity to apply for funding at the local level.
    - Part of the need for capacity at the local level can be addressed with strong climate information services. A demand for allocation of resources to developing these services emerges from interviews and surveys in all three countries. Effective services would provide climate information translated into guidance that is specific to decisions being made by a range of stakeholders, including guidance for crop management decisions by farmers and advice offered by extension services. Services should institutionalize building the capacity to use the information.
- A related point is that the flow of information between local and national levels needs to be improved. Policy making and resource allocation at the national level would advance

adaptation more effectively with better information about the diversity of conditions and needs at the local level as well as evidence about what has been done and what has worked well or not worked under different conditions at the local level. Decision makers at the local level need better information about policy plans and resources available at the national level.

- The need for collaboration and coordination of efforts emerges strongly from the interviews and surveys in all three countries. The respondents praise coalitions and platforms for coordination, such as COMNACC in Senegal. Collaboration and inclusive planning are necessary in order to bring information about a range of adaptation needs and experiences as well as expertise into the planning and policy processes. Coordination reduces duplication and omissions, and makes more effective use of limited resources.
- National planning would benefit from allocating more resources to collection, storage, and management of complete data sets collected at high spatial and time resolutions.

Research implications

- The primary demand for research and new information in the interviews and surveys is for climate projections, vulnerability assessments, and adaptation studies that are specific to local conditions. Agents make decisions at the local level, and local conditions differ with respect to climate conditions, cropping systems, governance, and socio-economic characteristics in each country in ways that affect appropriate adaptation strategies. Research and information need to demonstrate what are differences across conditions in order to be useable for decision making.
- Research is needed to guide how information about vulnerabilities and relevant adaptation options under different conditions in the country should inform national policy. The challenge lies in shaping policy that supports diverse programs tailored to local conditions.
- Decision makers need evidence about the effectiveness of adaptation strategies for different adaptation problems that are suited to local contexts, and guidance for investing in adaptation. The studies could empirically evaluate approaches to adaptation under different conditions and use the evidence to develop models that could predict benefits of adaptation under future conditions. The models should be tested with data.

Implications for engagement between researchers and stakeholders that can advance planning and adaptation

- Decision makers need capacity to guide the research process to produce outputs that are useful for making decisions, to understand the research methods used and the results, and to understand how to use the results. Building capacity among different types of decision makers, from national planners and policy makers to local government staff to farmers is essential to enable engagement between researchers and decision makers that results in useful and useable research outputs.
- The development of national planning and policy documents offers researchers an opportunity to influence the direction that the national government provides for adaptation in the country. Participating in the process of developing the documents influences more than the documents themselves. Engagement provides researchers with an opportunity to inform a range of decision makers, form partnerships, and improve the likelihood that diverse activities that arise from the discussions and partnerships are based on research.

- Researchers should be aware of the governance structure for adaptation planning and should engage with relevant government ministries, which wield substantial influence in the adaptation process.
- Researchers may exert more influence if they engage with coalitions of decision makers and with a broad range of decision makers. They should also partner with other projects to broaden the expertise in each project and coordinate efforts to improve the efficiency of resource allocation.
- Research should involve decision makers throughout the process, offering the opportunity to define research questions, shape the approach, provide feedback during the research, and collaborate on designing outputs.

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Appendices

Appendix A.1 Organizations that are most trusted sources of information for respondents' work in agriculture

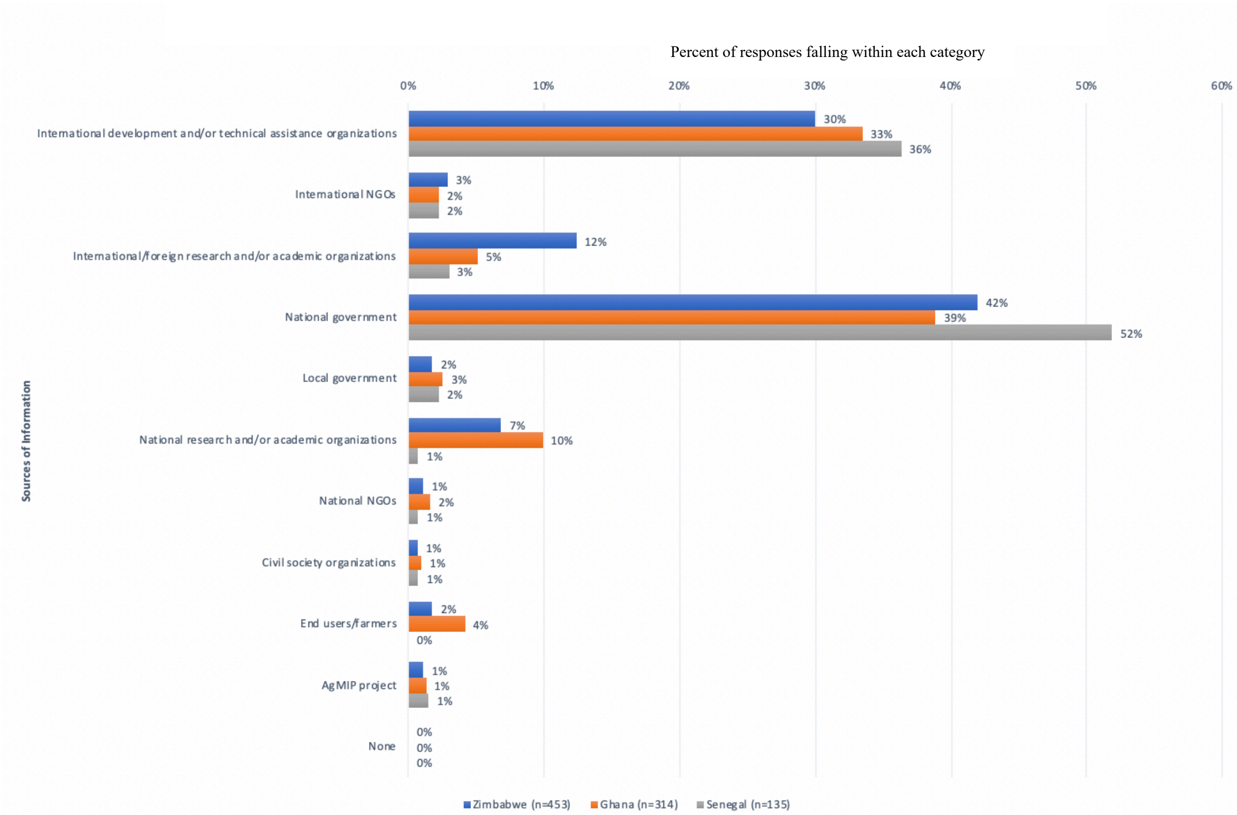

Figure A.1. Organizations that are most trusted sources of information for respondents' work on climate change in agriculture
Data are from the baseline surveys. The answer options to survey question include specific organizations as well as general categories, such as "national government" and "national research and/or academic organizations." For the purpose of the figure, we group responses that selected specific organizations under type of organization. Percentage is out of all responses given.

Appendix A.2 Obstacles to using existing information for work on climate change in agriculture in each country

The figures in this Appendix and in Appendices A.3 and A.4 show the results for each country individually. The answer options differed in the questionnaires in the three countries for these questions. The figures show percentage of respondents who selected each answer option.

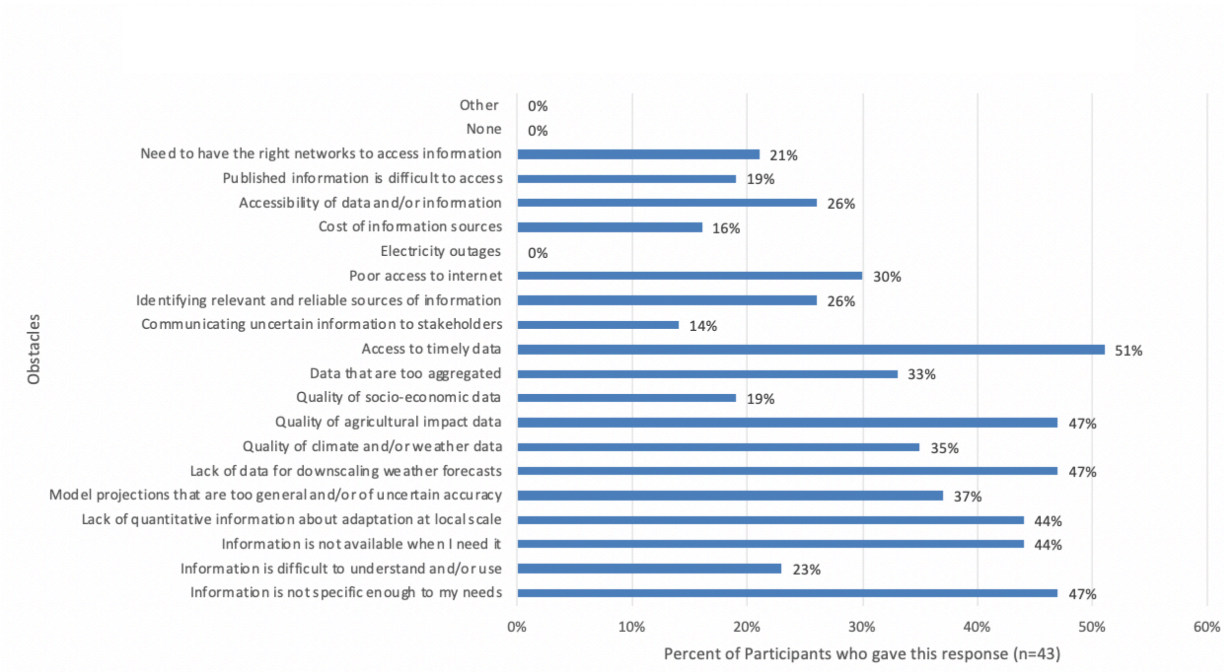

Figure A.2. ***Obstacles that impede use of existing information for respondents' work on climate change in the agricultural sector*** **in Ghana**

Data are from baseline surveys. Respondents could select multiple responses; therefore percentages of respondents who give each answer do not add up to 100% for each country.

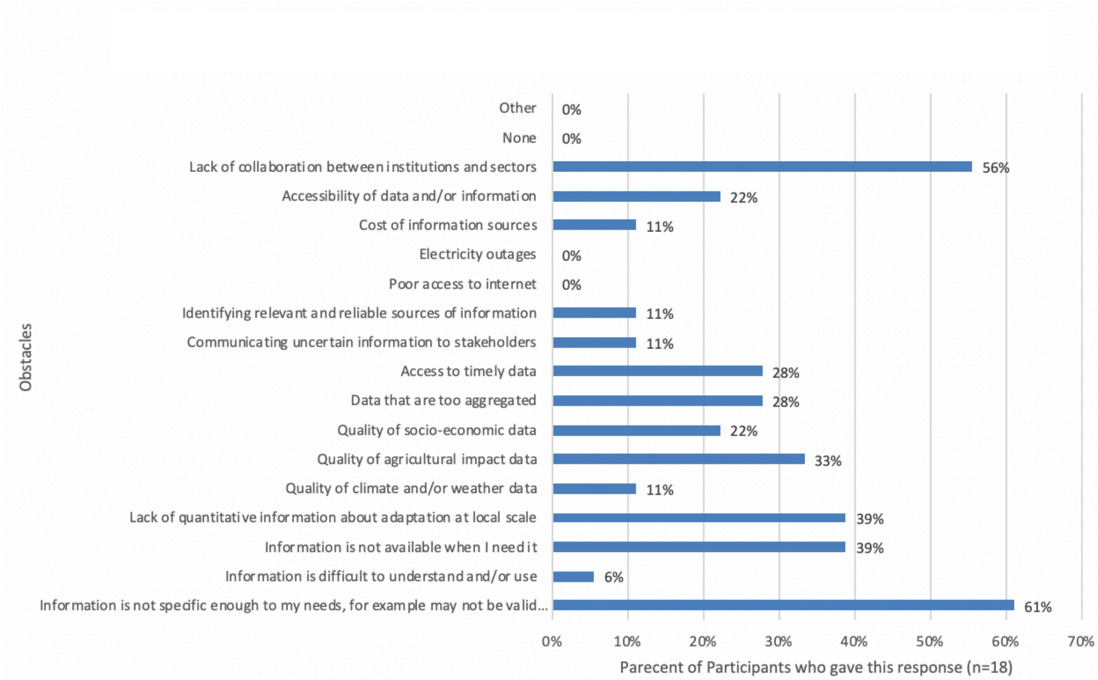

Figure A.3. ***Obstacles that impede use of existing information for respondents' work on climate change in the agricultural sector*** **in Senegal**
Data are from baseline surveys. Respondents could select multiple responses; therefore percentages of respondents who give each answer do not add up to 100% for each country.

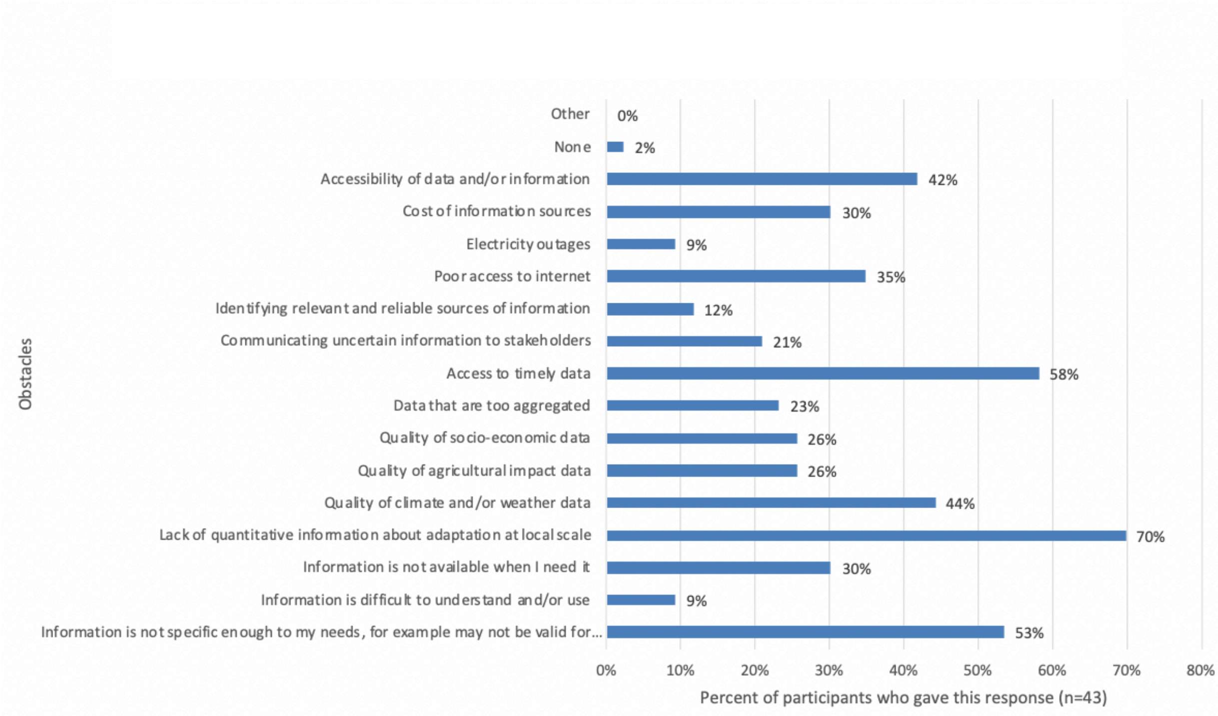

Figure A.4. ***Obstacles that impede use of existing information for respondents' work on climate change in the agricultural sector*** **in Zimbabwe**
Data are from baseline surveys. Respondents could select multiple responses; therefore percentages of respondents who give each answer do not add up to 100% for each country.

Appendix A.3 Needs for new information to support climate change work in agriculture

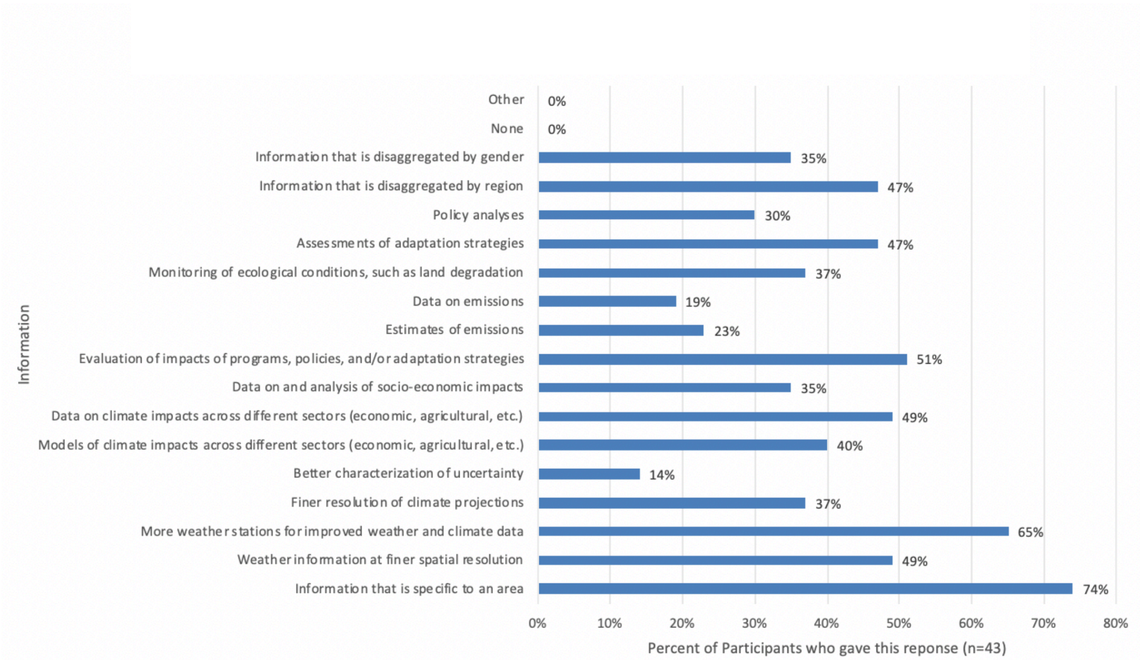

Figure A.5. Needs for information to support climate change work in agriculture in Ghana
Data are from baseline surveys. Respondents could select multiple responses; therefore percentages of respondents who give each answer do not add up to 100% for each country.

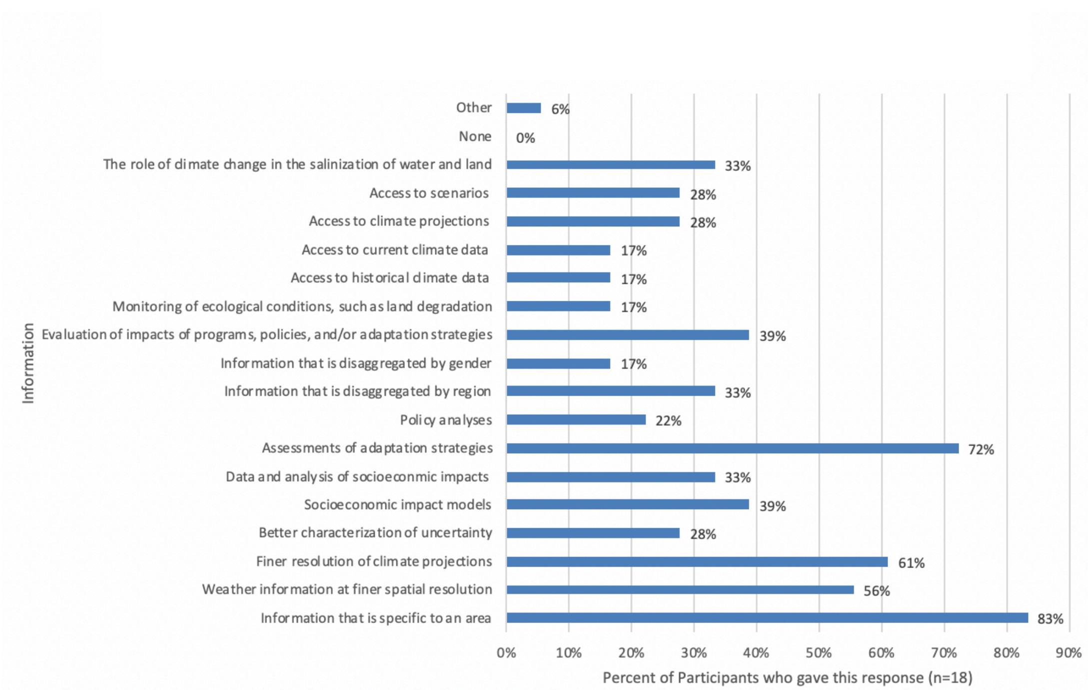

Figure A.6. Needs for information to support climate change work in agriculture in Senegal
Data are from baseline surveys. Respondents could select multiple responses; therefore percentages of respondents who give each answer do not add up to 100% for each country.

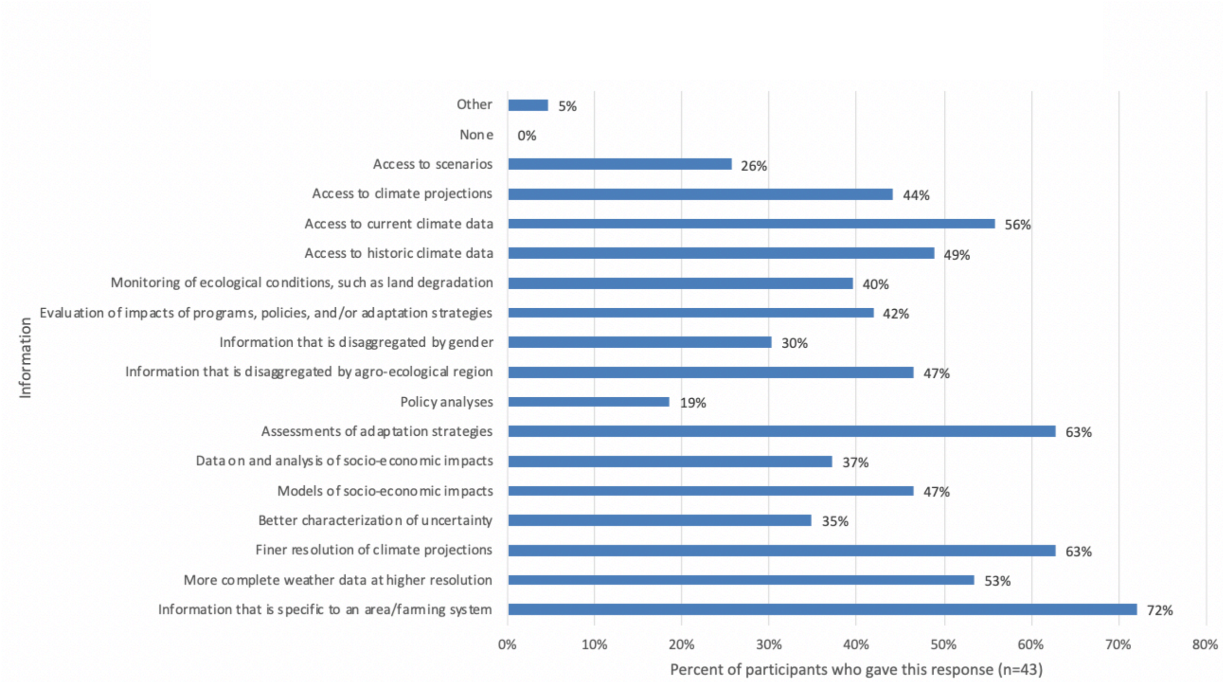

Figure A.7. Needs for information to support climate change work in agriculture in Zimbabwe
Data are from baseline surveys. Respondents could select multiple responses; therefore percentages of respondents who give each answer do not add up to 100% for each country.

Appendix A.4 Needs for research to support climate change work in agriculture

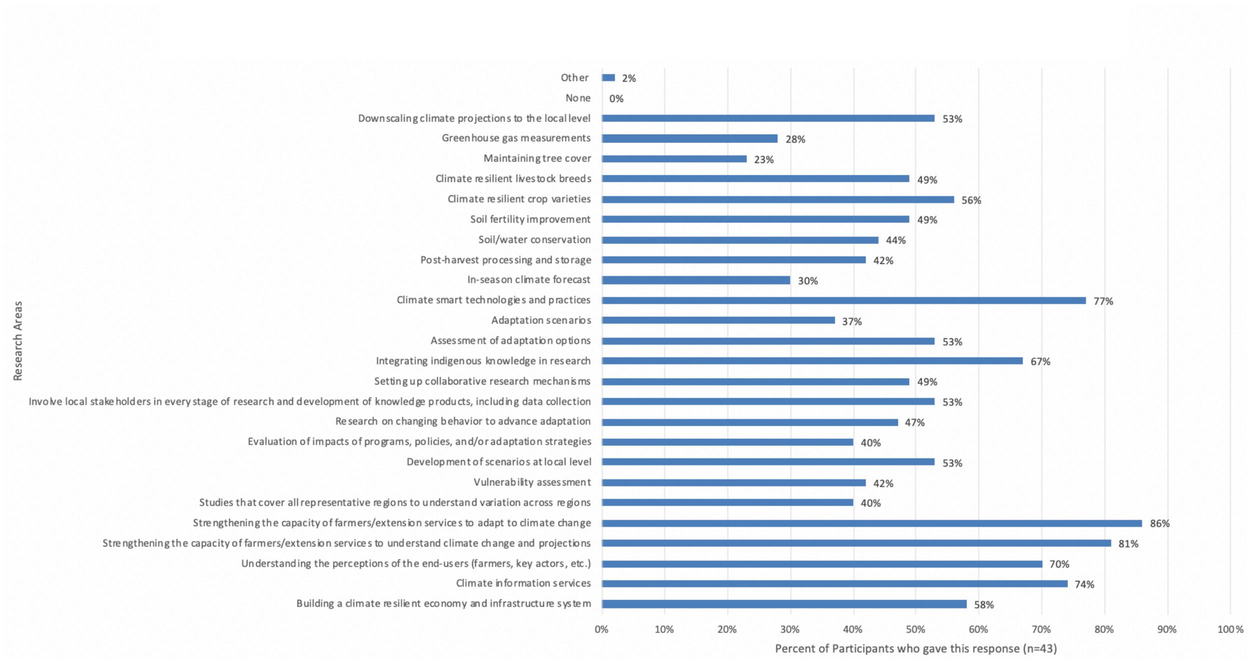

Figure A.8. Research needed to support respondents' work on climate change in the agricultural sector in Ghana

Data are from baseline surveys. Respondents could select multiple responses; therefore percentages of respondents who give each answer do not add up to 100% for each country.

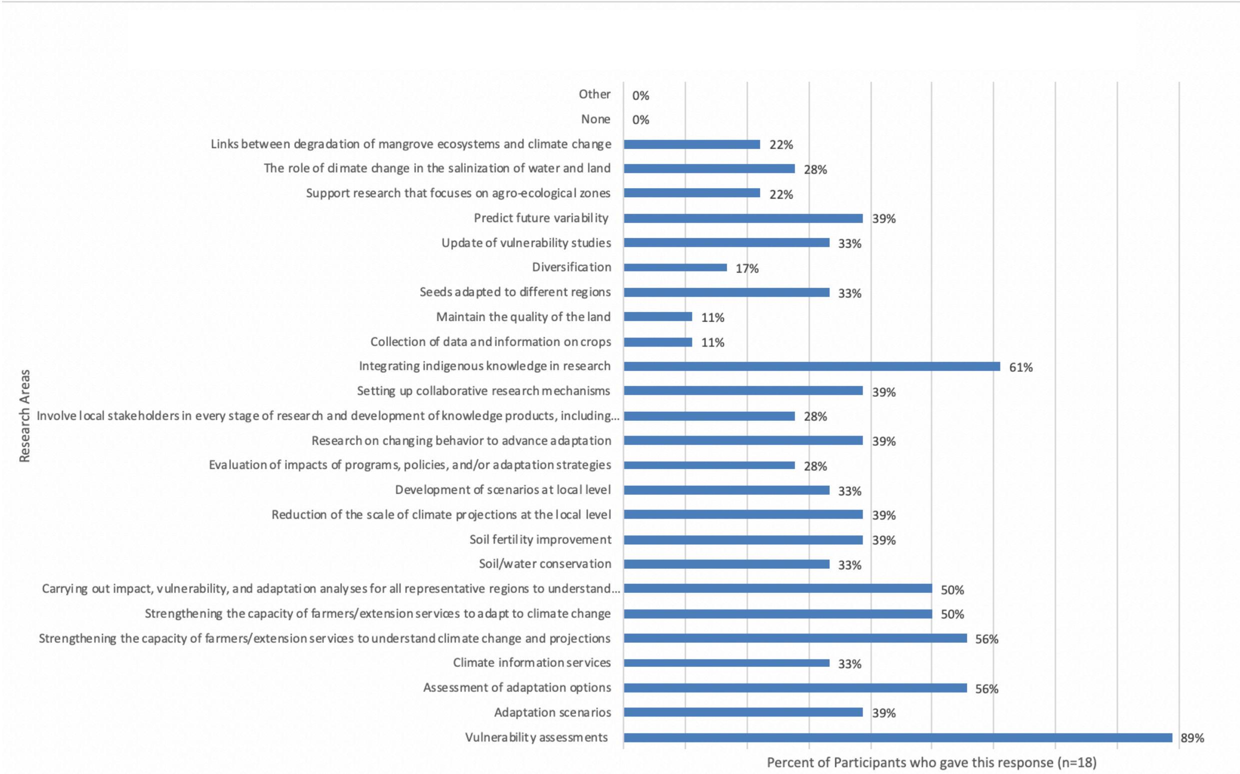

Figure A.9. Research needed to support respondents' work on climate change in the agricultural sector in Senegal
Data are from baseline surveys. Respondents could select multiple responses; therefore percentages of respondents who give each answer do not add up to 100% for each country.

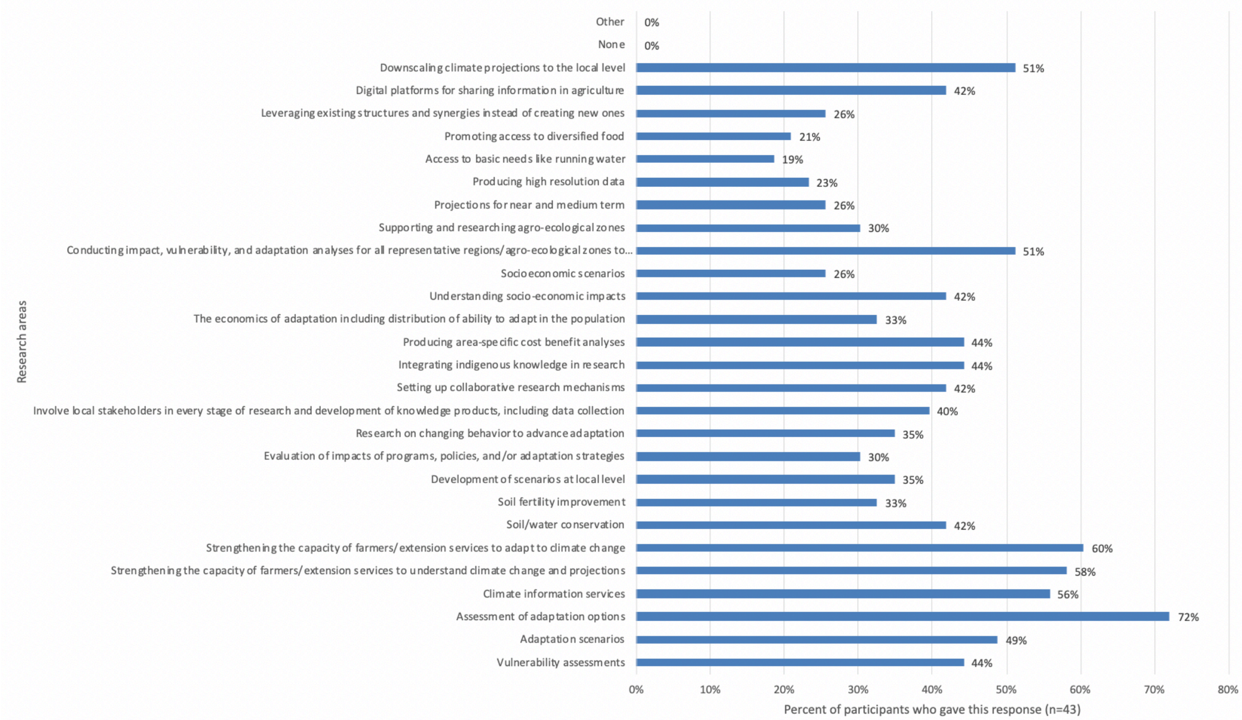

Figure A.10. Research needed to support respondents' work on climate change in the agricultural sector in Zimbabwe
Data are from baseline surveys. Respondents could select multiple responses; therefore percentages of respondents who give each answer do not add up to 100% for each country.

Appendix A.5 Characteristics of survey respondents

The survey respondents are a snowball sample identified by beginning with stakeholders known to the research teams in the three countries and including stakeholders identified by those contacts, with an effort to represent a range of categories of national and local stakeholders. The following figures show the characteristics of the respondents. A third to a half of the respondents represent the government, depending on the country, as shown in Figure A.11. The majority of respondents are at the senior levels of their organizations, with somewhat greater representation of middle and junior levels in Zimbabwe, shown in Figure A.12. Respondents fulfill a range of responsibilities, with the most frequently mentioned roles being program implementation, capacity building, coordination, and planning, shown in Figure A.13. They represent a range of areas of expertise, with the most frequently listed areas being vulnerability and adaptation to climate change, project management, and environmental management, shown in Figure A.14.

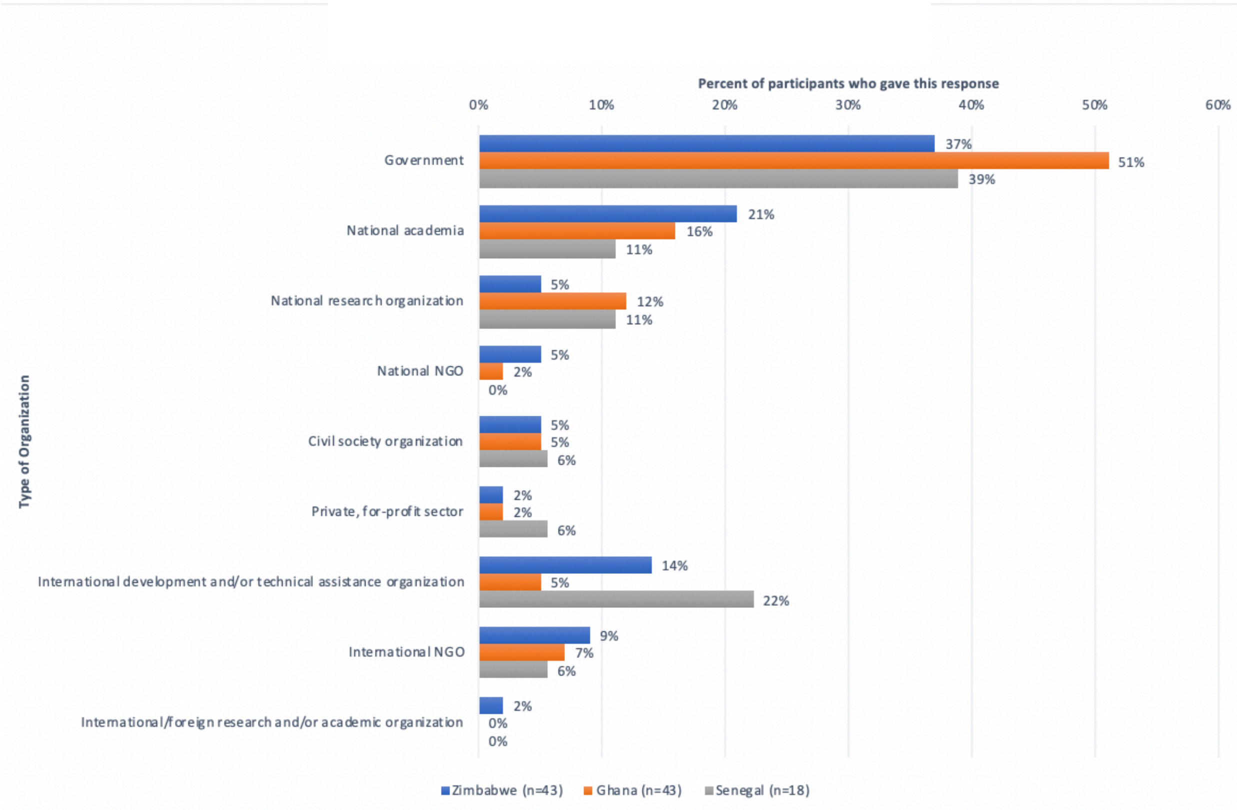

Figure A.11. Type of organization in which respondent is employed
Data are from baseline surveys. Respondents could select only one response.

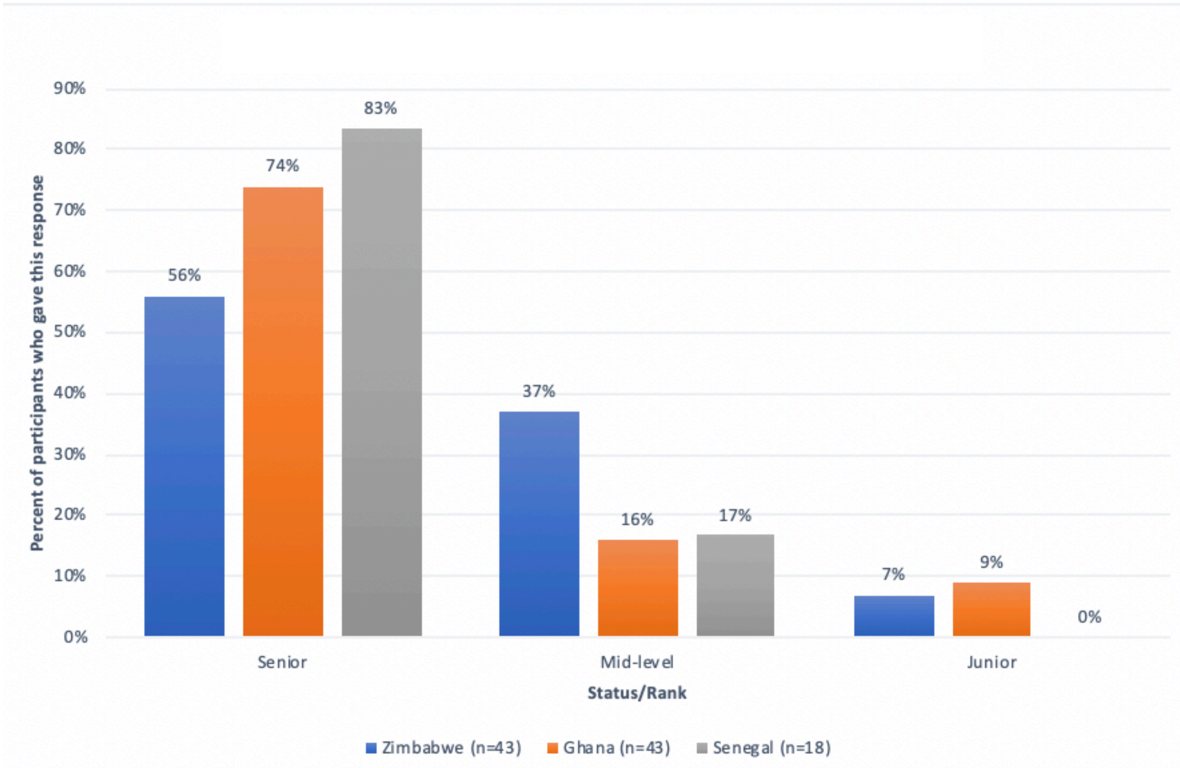

Figure A. 12. Respondent's status in their organization
Data are from baseline surveys. Respondents could select only one response.

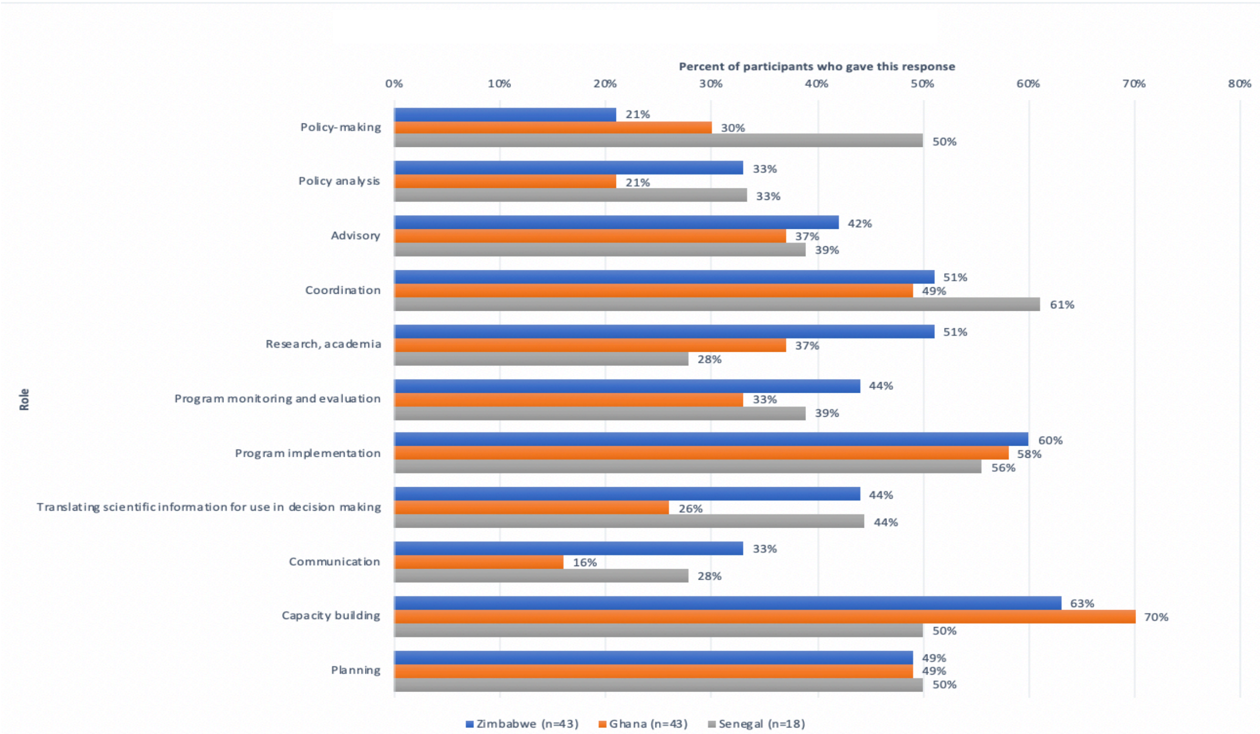

Figure A.13. Respondent's area of responsibility

Data are from baseline surveys. Respondents could select multiple responses; therefore percentages of respondents who give each answer do not add up to 100% for each country.

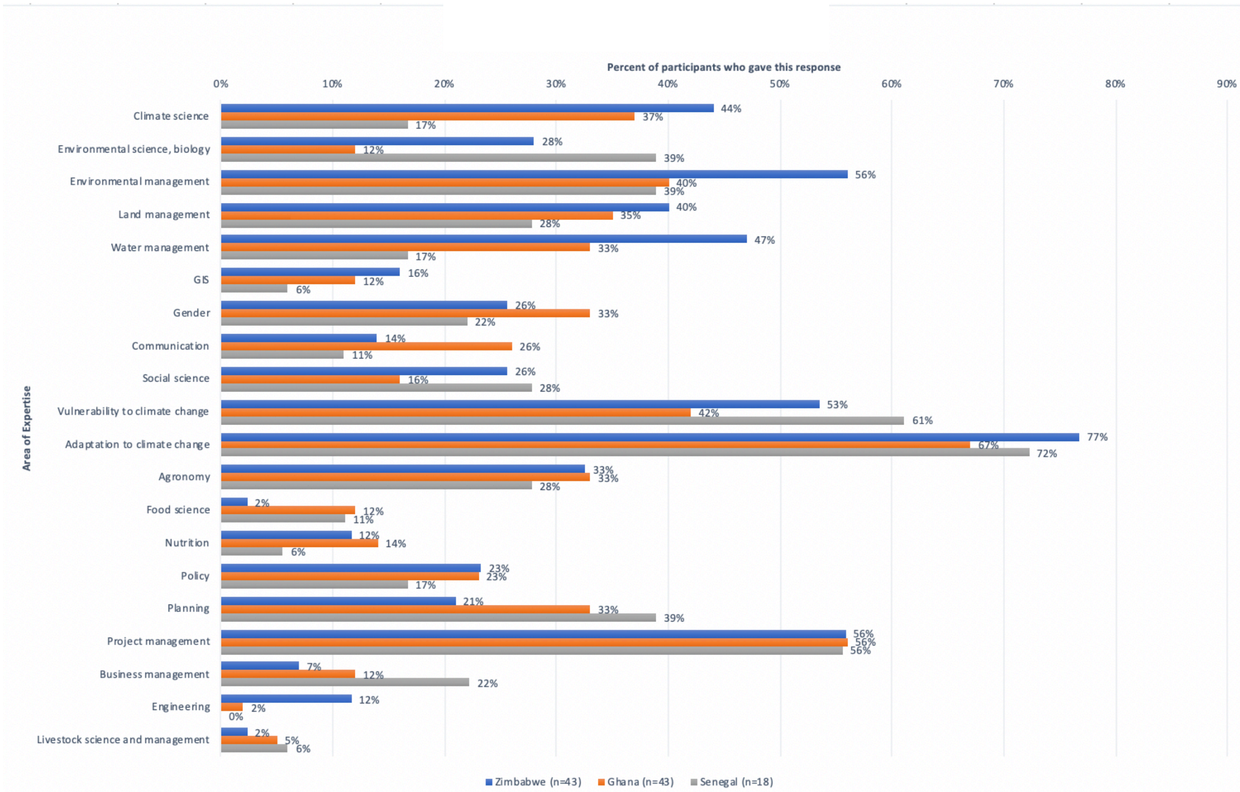

Figure A.14. Respondent's area of expertise

Data are from baseline surveys. Respondents could select multiple responses; therefore percentages of respondents who give each answer do not add up to 100% for each country.

AGRICULTURAL DEVELOPMENT, CLIMATE CHANGE AND ADAPTATION: TRADE-OFFS AND BENEFITS

A SYNTHESIS ANALYSIS OF THE AGMIP-CLARE A-TEAMS IN GHANA, SENEGAL, AND ZIMBABWE

The Agricultural Model Intercomparison and Improvement Project

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[3] Initiative Prospective Agricole et Rurale (*IPAR*)
[4] University of Ghana
[5] Matopos Research Institute
[6] Wageningen University & Research

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AGMIP-CLARE: KEY MODELING RESULTS FROM GHANA, SENEGAL, AND ZIMBABWE

The overall objective of the AgMIP-CLARE A-Teams is to support transitions to climate resilient farming systems, through improved policy decision making at national to regional levels. The specific objective was to build on AgMIP's prior work to increase national stakeholder capacity to develop evidence-based NAPs, NDCs and related agricultural development and climate change policies using science-based AgMIP Regional Integrated Assessment (RIA) products.

THE AGMIP REGIONAL INTEGRATED ASSESSMENT APPROACH

The AgMIP Regional Integrated Assessment (RIA) is a protocol based multi-model approach that links climate, crops, livestock and economic data and models to assess the impacts of climate change adaptation and mitigation of agricultural systems. Outcomes from the RIA can be used to support and improve information for policy decision making and planning. The RIA approach is built on the concept of the farm household and the farming system that it uses, the approach is fundamental to achieving a meaningful characterization of vulnerability and analysis of possible adaptation responses, particularly in the developing world context where farmers often rely on a complex mix of crops, livestock, aquaculture, and non-agricultural activities for their livelihoods (Antle et al., 2015; Valdivia et al; 2019). The RIA uses a participatory methodology with key stakeholders to identify jointly the questions that are relevant for the specific region, the indicators that should be used, the design of feasible adaptation packages to be tested, and the design the plausible future agricultural development pathways. This approach ensures that the results are directly relevant for the stakeholders involved.

The AgMIP RIA approach helps to understand and evaluate current conditions and the sensitivity of current agricultural farming systems to climate change. The stakeholders-scientists co-creation of agricultural development pathways help to project policies, investments, and institutional and socio-economic changes in the future. A set of different plausible pathways are developed to assess how agricultural systems can 1. evolve by following these pathways, and 2. How these future conditions may respond to climate change. The characterization of the agricultural systems under current and future conditions are key to assess the potential bio-physical, environmental and socio-economic tradeoffs, vulnerability and likely impacts on a heterogenous population of farm households. Likewise, this process is important to design adaptation strategies that are local-specific and that can improve farmers livelihoods and make the farming system more resilient to shocks. Feedback from stakeholders and dissemination of the results using an online platform (AgMIP's Impact Explorer) are part of the RIA process (See Figure 1).

In the AGMIP CLARE project, the RIA approach was extended to improve the linkage of data across scales. Linking the RIA to national and global scales helps to understand implementation of national policy interventions, how global markets and programs might affect agricultural systems as well as identify inconsistencies between policies developed at national level and implementation at local level. In this phase, the focus was on developing National level Representative Agricultural Pathways (RAPs). A key motivation to focus on National RAPs, is that agricultural policies are developed at National scale, and currently most of the countries are working on major proposals for agricultural development (e.g., Vision 2030) to meet the Sustainable Development Goals and their commitments under the Paris Agreement to deal with climate change (e.g., National Adaptation plans, Nationally Determined Contributions). Thus, policy decision makers need science-based information that can support their proposed policies.

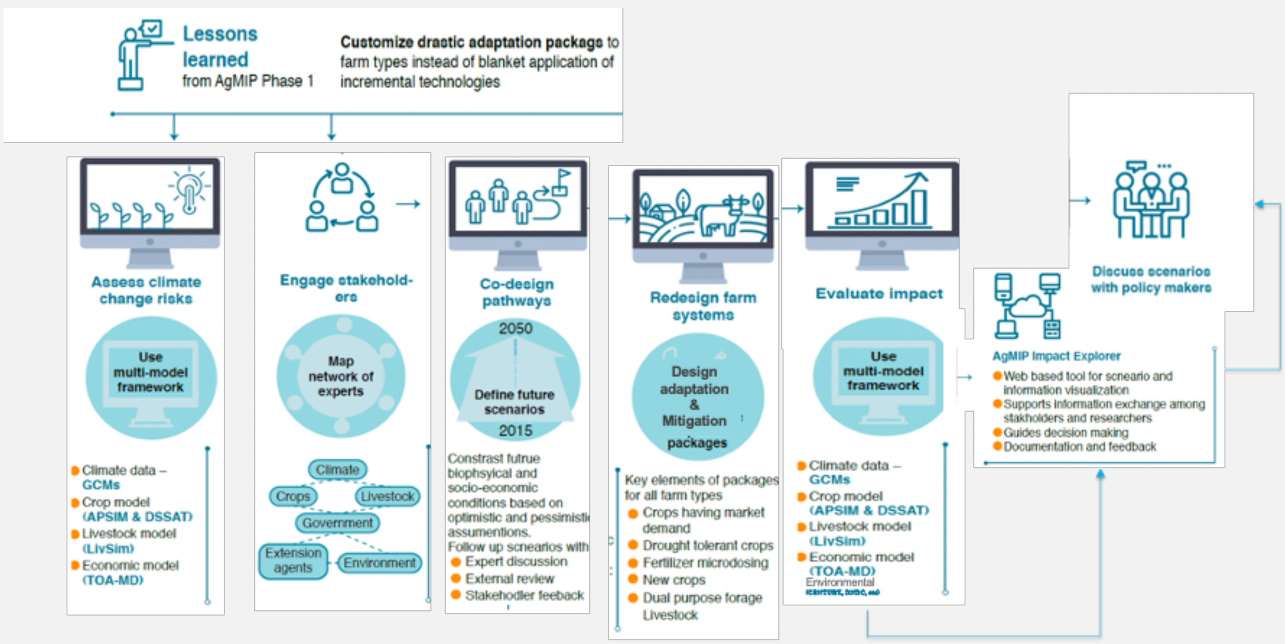

Figure 1. The AgMIP regional Integrated Assessment of Climate Change Impact, Vulnerability and Adaptation of Agricultural Systems. Customizing adaptation packages to reduce vulnerability to climate change under current and future conditions. Valdivia et al., 2019.

AGMIP-CLARE SIMULATION EXPERIMENTS

The simulation experiments will address three key research questions that help understand the impacts of climate change under current and future conditions and the role that agricultural development and adaptation strategies can play in the future. These questions have been aligned with the stakeholders' demand for science-based information to support development of agricultural policies and climate change adaptation plans (e.g., NAPs). Table 1 summarizes the 3 key research questions in the form of the simulation experiments conducted using the TOA-MD model (Antle and Valdivia, 2021) with input from crop models and other secondary data.

EC1 assess the impacts of climate change under current conditions. Data from 5 GCMs from RCP 4.5 and 5 from RCP 8.5 combined with 2 crop models were used as inputs to the TOA-MD resulting in 20 simulations[1].

EC2 assess the impacts of climate change under future conditions. Three Representative Agricultural Pathways that describe a Business-as-Usual pathway, an Unsustainable Development pathway and a Sustainable Development pathway, combined with the two RCPs and 2 crop models, were used as input to the TOA-MD model. In addition, a price sensitivity analysis for high and low prices analysis was conducted. The number of simulations were 60.

EC3 assess the benefits of adaptation strategies. The A-Teams and stakeholders designed an adaptation package to be tested using the TOA-MD model. This adaptation package was implemented for each scenario described in EC2. The number of simulations were 60.

The 3 sets of simulations were run again to estimate the Food Security Indicator as described below, and in the case of Zimbabwe, additional simulations were run to estimate the changes in GHG emissions.

Table 1. Simulation experiments conducted with the TOA-MD model.

Simulation Number	System 1	System 2	DESCRIPTION
EC1 (Q1)	S1	S2	Impact of climate change current conditions
EC2(Q3)	S3	S4	Impact of climate change under future socio-economic conditions (RAPs) and without adaptation
EC3 (Q4)	S4	S5	Benefits of adaptation under future conditions

[1] In the case of Zimbabwe, the A-Team only focused on the Hot/Dry and Hot/Wet scenarios as representative of the extreme results (negative and positive impacts on crop yields). In addition, the Zimbabwe team only used the high price range. The Zimbabwe team included livestock modeling and estimates of GHG emissions.

AGMIP-CLARE REGIONAL INTEGRATED ASSESSMENT BIO-PHYSICAL, ENVIRONMENTAL AND SOCIO-ECONOMIC OUTCOMES

Crop & Livestock Yields: Crop simulations are used to estimate crop or livestock productivity under current, future and adapted conditions (i.e., current and future climate and current, future and adapted management). The relative yield approach is used to estimate the change in the yield distribution in a population of farms due to climate change or other shocks and/or a change in management (See AgMIP Protocols v7 for details, Rosenzweig et al., 2017).

Farm Net Returns: The TOA-MD model estimates the mean net returns per farm (Currency/Farm/Time). Farm net returns distributions are estimated using farm production, prices, and production costs from each activity in the farm. Changes in mean farm net returns are computed for every simulation experiment.

Poverty Rate: The population Poverty Headcount rate (%) is estimated by the economic model. This indicator shows the proportion of households that are below a poverty line. In the AGMIP-CLARE analyses the poverty line was set at US$ 1/per/day.

Poverty Gap: The population Poverty Gap (%) estimated by the economic model shows the amount of average income as a proportion of farm income that farm households would need to increase in order to be above the poverty line.

Vulnerability: The vulnerability indicator (%) estimated by the TOA-MD represents the proportion of farms in a population that are vulnerable to climate change (i.e., farm households which farm income are at risk of decreasing due to climate change).

Net Economic Impact: The Net Economic Impact (%) is estimated by the TOA-MD by calculating the gains minus the losses as a percent of the mean net farm returns in a population of farms.

Adoption rate: The adoption rate (%) estimated by the economic model represents the percent of adopting farms when a new technology or system is introduced (e.g., an adapted technology). This indicator can be interpreted as the potential adoption rates, without considering other possible factors that may limit adoption.

Food Security: In the AgMIP-CLARE project, the Income Based Food Security (IBFS) indicator (Antle, Adhikari and Price, 2015) was implemented in the TOA-MD. The IBFS (%) estimates the proportion of farms that are below a threshold. This threshold represents the amount of income needed per person to purchase a nutritionally adequate food basket per day. Thus, the population that fall below this threshold are the households that can't afford a nutritionally adequate food basket and therefore, considered food insecure.

Green House Gas Emissions[2]: GHG emissions were calculated following the International Panel on Climate Change (IPCC) guidelines using the Tier 1 and Tier 2 methods (IPCC, 2006) where data availability allowed.

CH4_Enteric Fermentation. Methane emissions (CO2eq) from enteric fermentation in livestock were calculated following the Tier 2 methods for cattle, and Tier 1 for other livestock types, where animal numbers were multiplied with their methane emission factors. For cattle, the energy requirements for maintenance and different activities (pregnancy, lactation, work, growth) of the different animal types were considered together with the feed-dependent methane conversion factor. The values for these parameters were derived from the IPCC report using information on body weight, lactation and growth.

CH4_Animal Manure and waste, direct and indirect (CO2eq). Emissions from animal waste and manure management were calculated with the Tier 1 methods. For methane, this consisted of multiplying the animal numbers of different types with their specific methane emission factor. For N2O emissions from collected manure, we considered both direct and indirect (after volatilization) N2O emissions by applying the IPCC emission factors and loss fractions for dry lot and solid storage to stall-fed and other feeding regimes respectively.

N2O_Soil (direct & indirect) and CO2_fertilizer (CO2eq). Tier 1 methods were also used for the emissions from managed soils, where we considered direct N2O emissions from N inputs to agricultural soils, including the application of synthetic fertilizer, animal manure and crop residues left as mulch. Direct N2O emissions from urine and dung deposition during grazing were also considered. Indirect N2O emissions were included for atmospheric deposition from volatilized N and for leaching and runoff losses.

Total GHG: Total Green House Gas emissions (CO2eq) are estimated by adding N2O, CH4 and CO2 emissions from crop-livestock systems.

[2] GHG emissions were only estimated for the cop-livestock system in Zimbabwe.

AGMIP-CLARE'S FORESIGHT: DEVELOPING RAPS ACROSS SCALES: GLOBAL, NATIONAL AND SUB-NATIONAL

The process of developing RAPs across scales builds on the RAPs development protocols used in AgMIP's Regional Integrated Assessments of climate change and adaptation (Valdivia et al., 2015, 2021). The goal is to develop RAPs at National level that describe plausible futures aligned with the countries' visions of sustainable development and climate change policies. Regional (sub-national) RAPs incorporate policy and technological interventions set at national level and provide with storylines and quantifiable parameters to be used as inputs to crop-livestock and economic models. Additional RAPs representing different plausible future can be developed to assess impacts of climate change on farming systems under different future conditions. Key to this process is ensuring the consistency across the scales.

Scales: The RAPs development approach is a nested approach that links drivers and outcomes across scales (See Figure 2):

Global: Higher level pathways are used to define external drivers that may influence some of the National - and sub national- drivers. In AgMIP's scenario development, Shared Socio Pathways (SSPs) are used to describe the future global socio-economic conditions, including price and productivity projections. The SSPs are linked to different emission scenarios (Representative Concentration Pathways, RCPs) based on the storylines of the SSPs and what levels of emissions would be feasible under each pathway.

National: At this level, national RAPs include policies and agricultural plans that focus on the entire agricultural sector and cover the whole country. Drivers at national level might be influenced by external factors, like those in the SSPs or other aspects like international trade, international agreements and commitments (e.g., Paris agreement). National drivers in turn, influence the Regional (Sub-National) drivers.

Regional (*Sub-National):* At Sub-National level, we can define RAPs at two sub-levels. In cases where geographical division is important for the implementation of the national policies (e.g., State, Province, etc.), then RAPs can be developed for these levels as well as for more local -level conditions (e.g., district level, agro-ecological region, etc.). The regional RAPs contain most of the State/Province level narratives but are focused to the specific farming system to be analyzed (e.g., Crop-livestock system in Nkayi, Zimbabwe). The quantification of key drivers of these RAPs are used to parameterize crop, livestock and regional and national economics models.

LINKING REGIONAL RAPS TO NATIONAL RAPS

Development of Regional RAPs follow these overall steps:

1. The process starts by characterizing the current state of the farming system, including the current policy conditions.

2. Using narratives of future global socio-economic scenarios (SSPs), information about the national policies (in some cases projected into the future) and with input from stakeholders and the team of scientists and experts, a description of "future states" of the agricultural farming system are created (RAP narratives).

3. With the definition of the future scenarios, an iterative process is carried out to identify the key drivers of change (policy/institutional, economic, technology and bio-physical) that would support the RAP narrative (i.e., the future conditions of the agricultural system).

4. Regional RAP is finalized by defining qualitative and quantitative changes for key drivers. The process starts over to develop additional regional RAPs.

In the AgMIP-CLARE project, regional and national RAPs were developed following the process described in Figure 3. The steps followed to link national level RAPs to regional RAPs were:

1. Characterize the current state of the agricultural sector in the country. Use of available information to define the structure of the government, organizations and identify key stakeholders (those who can be part of the process during the project, and the high-level stakeholders to whom the results will be presented).

2. Identify and describe the long-term vision of the country using Sustainable Development plans, Strategic Vision, National Adaption Plans, etc. Focus on the agricultural sector, but also be inclusive of policies and plans from other sectors that may have an effect on the agricultural sector (e.g., energy, health, education, etc.).

    - The strategic vision or sustainable development plans usually have key pillars around which policies and interventions are built to achieve goals regarding environmental protection, achieve economic efficiency, agricultural sustainable development, energy production, social equity, food security, etc. In many cases a set of indicators are associated with these plans.

    - The goal was to develop contrasting RAPs, thus, after finalizing the RAPs that represent the future state under the strategic visions or country's sustainable development plans, a similar iterative process to create additional RAPs was followed, then pathways representing Business as Usual (BAU) and Unsustainable Development conditions were developed.

3. Using the above information, and the defined global SSPs, the team, invited experts and stakeholders define the plausible future states of the agricultural sector and crafted the main 'RAP narratives'.

4. The next step is an iterative process that starts with identifying the key drivers of change (use of the strategic vision, sustainable development plans, and other documents to determine these drivers). National and agricultural policies define the policy/institutional and socio-economic conditions of the National RAPs. The Policy Matrix (defined below) was used to identify the different types of policies that supports contextualizing the RAP and define the key variables that may have a direct or indirect effect on the sub-national level drivers. Examples of drivers and specific variables are shown in Table 1.

    - Once identified the key drivers, a process similar to the regional RAPs is followed: Using the DevRAP matrix, for each driver, a direction and magnitude of change is proposed. Storylines to justify these changes are elaborated and levels of agreement are assessed.
    - Variables were assigned to team members, experts and stakeholders to research about the plausible trends following the overall narrative. All documents, studies, papers, etc used were documented and stored on a shared Google Drive folder.
    - The team revised the storylines as they are crafted to make sure there is internal consistency across the drivers.
    - The output of the iterative process is a full draft of National RAPs.
    - The next step is to revise the regional RAPs to make sure there is consistency across scales.
    - The team and stakeholders meet and review and discuss the full Regional and National RAPs.

5. New RAPs are then be developed by following the same iterative process with the main goal of identifying those drivers that would lead to an alternative future state (e.g., a less sustainable development oriented RAP).

6. The quantification of the revised regional RAPs will be input to the TOA-MD model and complement the data needed to implement the RIA. Outputs from this process will also be included in the INaRA process.

MAPPING NATIONAL POLICIES TO RAPS

In order to help with the process of identifying the key drivers from National policies and link them to the RAP process, we use a Policy Matrix tool created in Excel (Mapping national policies to RAPs.xlsx).

This matrix lists all drivers and specific variables that are key to describe the national and agricultural policies in the context of the country's strategic vision, sustainable development plans and climate change plans (NAPs, NDCs, etc). The matrix also allows to identify how they may influence regional RAPs and how they are influenced by global scenarios (SSPs).

The policy matrix helps to categorize the type of policies as: 1. Enabling; 2. Incentivizing; 3. Mandatory; 4. climate policies; and 5. guidelines or programs implemented or planned by the government, see Figure 4.

The team uses this matrix to evaluate importance of each policy and how these can be incorporated and quantified in the different RAPs. In addition, climate policies are used to develop assumptions about the implementation of future climate policies (Shared Policy Assumptions, SPA).

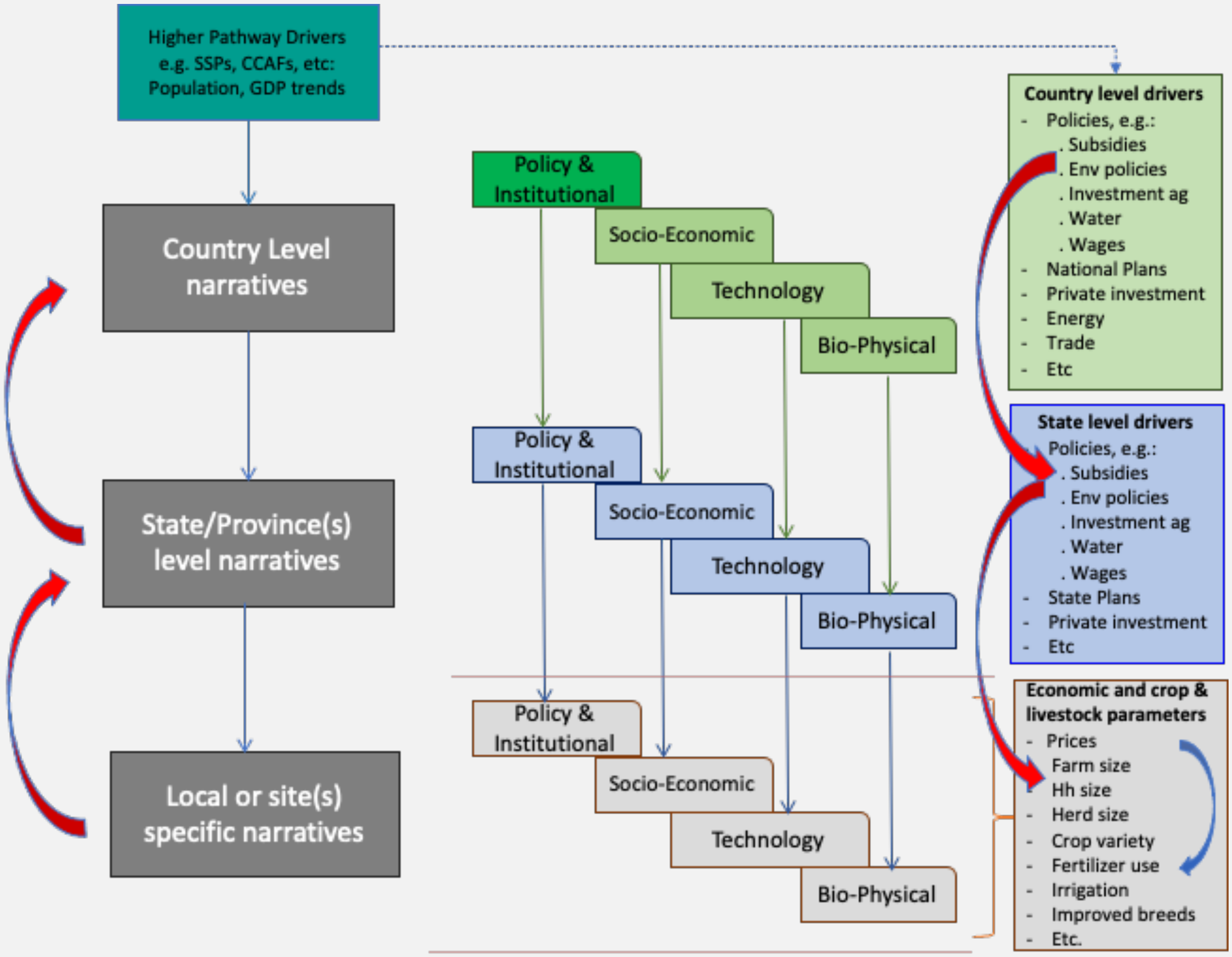

Figure 2. Nested approach across scales to develop Representative Agricultural Pathways:

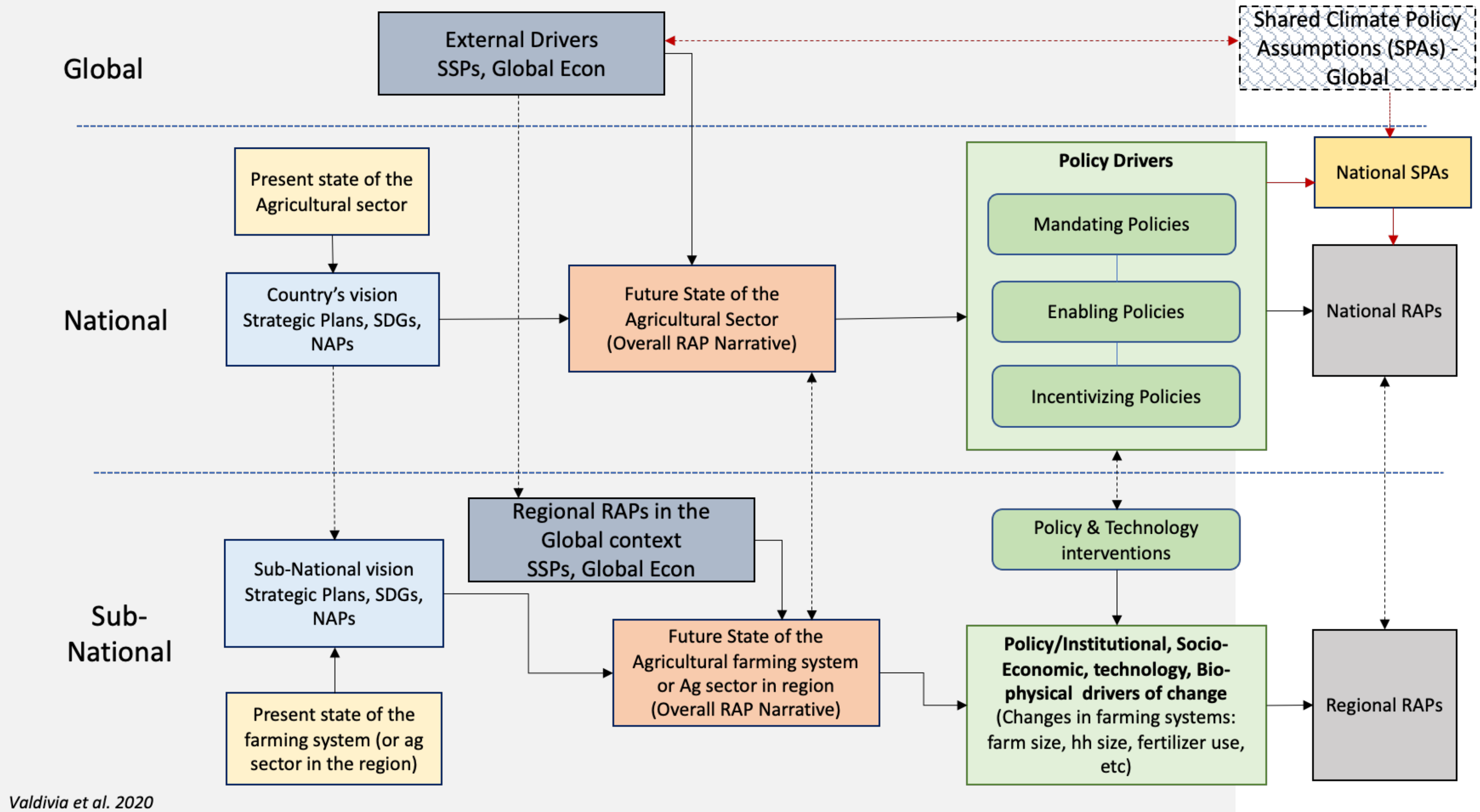

Figure 3. Process to develop and link RAPs across Global-National-Sub-National scales.

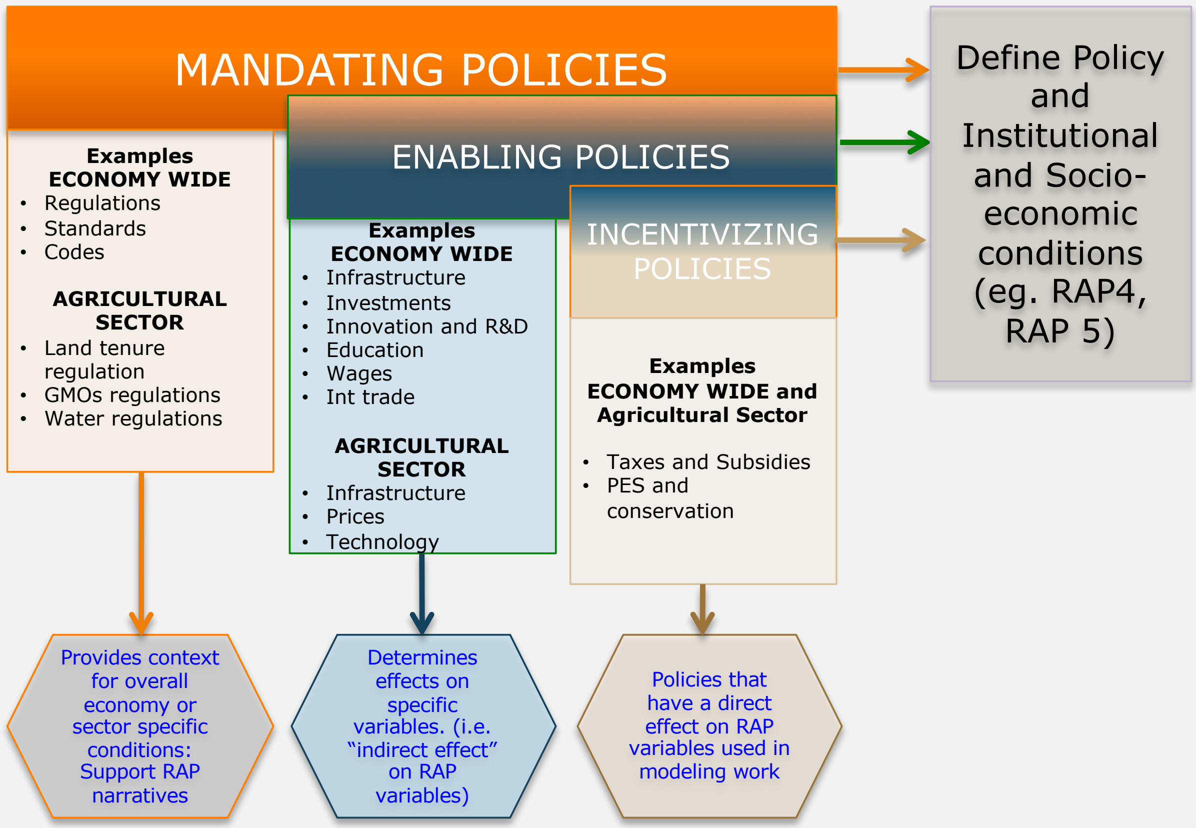

Figure 4. Components of the Policy Matrix tool: National level Policies and linkages to RAPs

Table 2. Example of drivers and variables for National level RAPs

Driver	Variables
Regional Development	Context: Regional; West Africa (ECOWAS)
Economic growth	GDP, Agricultural GDP share
Population	Population growth, migration rural to urban
Literacy	Education-investment, programs
Healthcare	Investment on healthcare, programs
Land Use	Expansion, change to new crops (as policy, incentives, land protection, etc)
Energy	Fossil fuel use, policies
Agricultural policies	Subsidies, taxes, quotas, policies on specific commodities, Payment for Ecosystem Services
Food production policies	GMOs, organic, etc
Environmental policy	Conservation policies, etc
Climate change policies	NAPs, NDCs strategies
Trade policies	tariffs, imports/exports
Technological change	R&D investment
Water	regulations, bio-physical conditions
Biodiversity	Regulations on biodiversity, incentives, PES
Level of governance	National and Sub-National
Sub-national development	Rural development policies
Social policy	Education, equity (gender)
Markets	Investment, infrastructure, price controls/ceiling

RESULTS

PARAMETERS FROM RAPS AND ADAPTATION PACKAGES FOR CROP-LIVESTOCK AND ECONOMIC MODELS

Tables 3-5 describe the parameters used to run the simulations based on changes from current to future conditions according to the different RAPs. Price and productivity trends for the specific commodities in each country were obtained from output data from IFPRI's IMPACT model. These trends were estimated as % change in crop yields and prices from current conditions to 2035.

Changes in farm and household characteristics were important across the 3 teams. Changes in farm size, household size, herd size and off farm income were some of the key drivers in the RAPs. Policies such as subsidies or investments on infrastructure to improve farmers access to input and output markets were also important to determine prices of inputs as well as changes in their use (e.g., fertilizers, seeds, etc). In some cases, changes in land allocation, or inclusion of new crops were also part of the RAPs.

The adaptation packages initially focused mostly on genetic improvement (i.e., improved crop varieties). However, after analyzing preliminary results, it was clear that the adaptation packages should be tailored to the different types of farms, or to the crops or activities that contribute the most to farm income. In the case of Zimbabwe for example, 3 different adaptation strategies that combined different policy and investments with changes in agricultural and livestock management and structure were analyzed.

Table 3. Senegal Parameters from RAPs and Adaptation Package for crop-livestock and economic models

	Business As Usual				Sustainable Development				Fossil Fuel			
Productivity trends -2035												
Maize	0.85				0.9				0.82			
Peanut	1.39				1.15				1.15			
Millet	0.93				0.95				0.91			
Livestock	0.88				0.88				0.88			
Price trends - 2035	*High Price*		*Low Price*		*High Price*		*Low Price*		*High Price*		*Low Price*	
	No CC	*With CC*	*No CC*	*With CC*	*No CC*	*With CC*	*No CC*	*With CC*	*No CC*	*With CC*	*No CC*	*With CC*
Maize	1.21	1.24	1.21	1.02	1.25	1.29	1.25	1.03	1.19	1.27	1.19	1.06
Peanut	0.73	0.97	0.73	1.24	0.68	0.88	0.68	1.31	0.78	1.07	0.78	1.37
Millet	1.09	1.19	1.09	1.08	1.02	1.14	1.02	1.12	1.18	1.34	1.18	1.13
Livestock	1.10	1.11	1.10	1.01	1.15	1.16	1.15	1.01	1.06	1.07	1.06	1.01
Household size	11.63	11.27	13.09	13.10	8.73	8.45	9.82	9.83	11.63	11.27	13.09	13.10
Off-farm income (USD)	1086.90	1041.61	1460.84	981.71	1086.90	1041.61	1460.84	981.71	1086.90	1041.61	1460.84	981.71
Land allocation	*Strata 1*	*Strata 2*	*Strata 3*	*Strata 4*	*Strata 1*	*Strata 2*	*Strata 3*	*Strata 4*	*Strata 1*	*Strata 2*	*Strata 3*	*Strata 4*
Farm size (ha)	7.47	7.16	8.64	8.64	9.95	9.55	11.52	11.52	6.64	6.36	7.68	7.68
Maize share (%)			15%	13%			15%	13%			15%	13%
Peanut share (%)	38%	39%	41%	42%	38%	39%	41%	42%	38%	39%	41%	42%
Millet share(%)	29%	27%	26%	27%	29%	27%	26%	27%	29%	27%	26%	27%
Other crops share (%)	33%	34%	33%	32%	33%	34%	33%	32%	33%	34%	33%	32%
Herd size (TLU)	3.0	1.4	9.6	3.4	1.6	0.8	5.1	1.8	3.0	1.4	9.6	3.4
Adaptation package - Relative change in crop yields and livestock revenues												
	Strata 1	Strata 2	Strata 3	Strata 4	Strata 1	Strata 2	Strata 3	Strata 4	Strata 1	Strata 2	Strata 3	Strata 4
Maize yields			1.08	1.1			1.13	1.16			1.07	1.08
Peanut yields	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03	1.03
Millet yields	1.05	1.13	1.14	1.14	0.95	0.95	1.12	1.13	1.15	1.13	1.15	1.14
Livestock revenue	2.8		2.8		2.8		2.8		2.8		2.8	

Strata 1: Farms with no maize with livestock. Strata 2: Farms with no maize and no livestock. Strata 3: Farms with maize and livestock. Strata 4: Farms with maize no livestock

Table 4. Zimbabwe Parameters from RAPs and Adaptation Package for crop-livestock and economic models

	Business-as-usual (BAU)			Sustainable development (SD)			Unsustainable development (UD)		
	RAPS								
Productivity trends (%)									
.Maize	2.08			2.26			2.08		
.Sorghum	1.51			1.62			1.51		
.Groundnuts	1.25			1.32			1.25		
.Cattle	1.45			1.55			1.45		
.Goats	1.04			1.13			1.04		
Price trends (%)	No CC		With CC	No CC		With CC	No CC		With CC
.Maize	1.19		1.26	1.25		1.29	1.19		1.26
.Sorghum	1.23		1.34	1.19		1.29	1.23		1.34
.Groundnuts	1.3		1.32	1.32		1.33	1.3		1.32
.Cattle	1.06		1.08/1.07	1.18/1.11		1.2/1.12	1.06		1.08/1.07
.Goats	1.06		1.07	1.19		1.2	1.06		1.07
Farm and HHs characteristics	0 cattle	1-8 cattle	> 8 cattle	0 cattle	1-8 cattle	> 8 cattle	0 cattle	1-8 cattle	> 8 cattle
Household size (persons)	1.05	1.05	1.05	1.1	1.1	1.1	1.1	0.9	0.9
Off-farm income (USD)	1.1	1.1	1.1	1.2	1.2	1.2	1.5	1.1	1.1
Farm size (ha)	1.2	1.2	1.2	1.2	1.4	1.4	0.6	1.8	1.8
Cropland allocation (%)									
.Maize	50	56	55	40	35	35	100	50	35
.Sorghum	32	28	30	10	15	15	0	0	15
.Groundnut	18	16	15	30	20	20	0	20	20
.Mucuna	0	0	0	20	30	30	0	30	30
Cattle herd size (TLU)	1	1.2	1.2	5*	1.6	1.6	1	1.8	1.8
Goat flock size (TLU)	1.2	1.2	1.2	2*	1.5	1.5	1.1	1.6	1.6
Cattle offttake (%)	5	5	5	20	20	20	20	20	20
Goat offttake (%)	5	5	5	20	20	20	20	20	20
	Adapation and mitigation packages								
A1. Change in crop varieties	Shift to drough tolerant varieties			Shift to drough tolerant varieties			Shift to drough tolerant varieties		
A2. Change in cropland allocation (%)				Crop diversification					
.Maize				18	18	18			
.Sorghum				18	18	18			
.Groundnut				25	25	25			
.Mucuna				17	17	17			
.Leucaena				22	22	22			
A3. Change in herd composition, offtake				Shift cattle to goats					
.Cattle herd size (TLU)				0.5*	0.5*	0.5**			
.Goat herd size (TLU)				1.5	1.5	1.5			
.Cattle offtake (%)				20	20	20			
.Goat offtake (%)				35	35	35			

Notes: HH=Household; TLU=Tropical Livestock Unit; Cattle = 1.14 TLU; goats and sheep = 0.11 TLU.

*Everyone who had no cattle or goats before would have at least five heads of cattle and/or five heads of goats

**Half the households convert all cattle to goats

Table 5. Ghana Parameters from RAPs and Adaptation Package for crop-livestock and economic models

	Business as Usual (BAU)		Sustainable Development (SD)		Fossil Fuel (FF)	
Productivity trends (%)	RAPS					
Maize	1.31		1.37		1.26	
Peanut	1.21		1.25		1.18	
Sorghum	1.43		1.48		1.38	
Millet	1.47		1.51		1.43	
Rice	1.36		1.39		1.33	
Vegetables	1.28		1.33		1.24	
Livestock	1.15		1.50		1.40	
Price trends (%)	*No CC*	*With CC*	*No CC*	*With CC*	*No CC*	*With CC*
Maize	1.21	1.24	1.25	1.29	1.19	1.26
Peanut	1.00	1.18	0.93	1.15	1.06	1.34
Sorghum	1.20	1.27	1.19	1.29	1.23	1.34
Millet	1.09	1.19	1.02	1.14	1.18	1.34
Rice	1.08	1.18	1.00	1.11	1.17	1.35
Vegetables	1.05	1.12	1.04	1.11	1.07	1.18
Livestock	1.10	1.11	1.15	1.16	1.06	1.07
	Maize-based farms	*Non-Maize-based farms*	*Maize-based farms*	*Non-Maize-based farms*	*Maize-based farms*	*Non-Maize-based farms*
Household (size)	7.06	6.33	7.53	6.75	6.59	5.90
Off-farm income ($)	877.91	759.79	1004.39	869.25	929.99	804.87
Farm size (ha)	3.23	3.18	3.49	3.45	3.76	3.71
Maize share (%)	16.48	NA	16.48	NA	16.48	NA
Peanut share (%)	19.96	12.83	19.96	12.83	19.96	12.83
Sorghum share (%)	25.47	30.74	25.47	30.74	25.47	30.74
Millet share (%)	20.65	33.15	20.65	33.15	20.65	33.15
Rice share (%)	17.43	23.28	17.43	23.28	17.43	23.28
Adaptation package						
	Maize-based farms	*Non-Maize-based farms*	*Maize-based farms*	*Non-Maize-based farms*	*Maize-based farms*	*Non-Maize-based farms*
Seed cost						
Maize	46.0526	NA	46.0526	NA	46.0526	NA
Peanut	87.3158	87.3158	87.3158	87.3158	87.3158	87.3158
Sorghum	22.1053	22.1053	22.1053	22.1053	22.1053	22.1053
Change in Producivity (relative yields)*						
Maize (% change yields)_APSIM	1.01-1.05 [1.03]	NA	1.03-1.04 [1.04]	NA	1.00-1.02 [1.01]	NA
Maize (% change yields)_DSSAT	1.05-1.09 [1.07]	NA	1.08-1.11 [1.10]	NA	1.02-1.13 [1.07]	NA
Peanut (% change yields)_APSIM	1.00-1.02 [1.01]	0.99-1.01 [1.00]	1.01-1.02 [1.01]	1.00-1.00 [1.00]	1.13-1.19 [1.19]	0.99-1.02 [1.00]
Peanut (% change yields)_DSSAT	1.11-1.19 [1.14]	1.10-1.21 [1.15]	1.08-1.10 [1.09]	1.07-1.10 [1.09]	1.00-1.01 [1.15]	1.12-1.22 [1.16]
Sorghum (% change yields)_APSIM	1.00-1.01 [1.00]	1.01-1.06 [1.02]	1.00-1.01 [1.00]	1.00-1.02 [1.01]	1.00-1.01 [1.00]	1.01-1.02 [1.01]
Sorghum (% change yields)_DSSAT	1.04-1.08 [1.05]	1.04-1.08 [1.05]	1.04-1.05 [1.04]	1.04-1.05 [1.04]	1.03-1.07 [1.05]	1.03-1.06 [1.05]
Millet (% change yields)	1.11	1.11	1.11	1.11	1.11	1.11
Rice (% Change in revenues)	1.49	1.49	1.49	1.49	1.49	1.49
Rice (% Change in variable cost)	1.03	1.03	1.03	1.03	1.03	1.03
Vegetables (% change in net returns)	1.28	1.28	1.28	1.28	1.28	1.28
Livestock (% change in revenues)	1.21	1.21	1.21	1.21	1.21	1.21
Livestock (% change in variable cost)	1.27	1.27	1.27	1.27	1.27	1.27

* relative yields are shown as ranges with the mean values in brackets [x]

IMPACTS ON SMALLHOLDER FARM HOUSEHOLDS IN SEMI-ARID REGIONS OF GHANA, SENEGAL AND ZIMBABWE

BIO-PHYSICAL IMPACTS

Climate change impacts on crop yields across the 3 countries are mostly negative. Drier conditions (Hot and dry or Cold and dry climate scenarios) lead to large yield decreases for maize, sorghum, millet, and livestock. Groundnut, however, shows a positive response to most climate change scenarios due to CO2 fertilization. Given the importance of groundnuts to the farming systems, in particular in West African countries (i.e., contribution of groundnuts to farm income), increasing returns to groundnuts tend to offset some of the losses from the other activities on the farm as it is shown below. Maize on the other hand, is the crop that have larger losses across the 3 countries. Improved farming conditions, access to fertilizers and other inputs under future conditions (RAPs) do not seem to improve maize yields, in partly because poor soil conditions limit the response to management improvements. However, adaptation of maize systems based on increased use of improved seeds and mineral and organic fertilizer seem to improve maize yields under climate change conditions, in particular for the scenarios where rainfall increase (e.g., How and wet climate scenario).

Figure 5 shows the ranges of simulated crop and livestock yield changes due to climate change (Current CC and Future CC) and adaptation (Future CC Adaptation) for the different GCMs, crop models and strata. Changes in yields of non-simulated crops were obtained from secondary information and included as part of the RAPs.

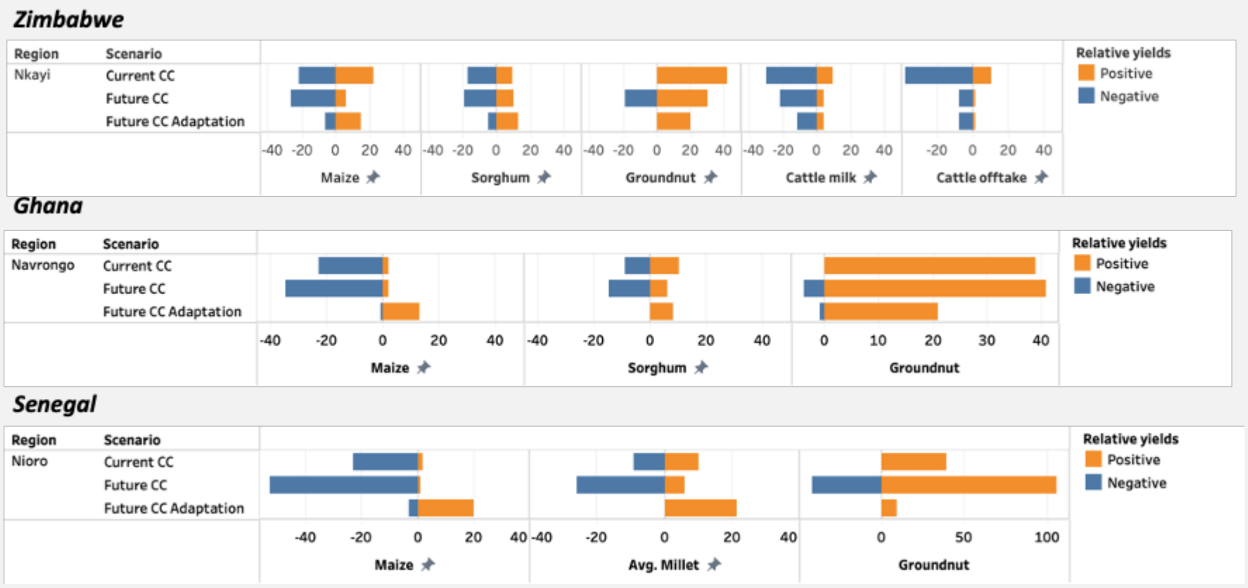

Figure 5. Climate change impacts on crop and livestock yields

ECONOMIC IMPACTS

CURRENT CONDITIONS

Current conditions in the farming systems of the three sites that were modeled are characterized by low productivity levels, low income and high poverty rates and food insecurity. Small farm sizes and large households contribute to this situation. Farms that own livestock seem to do better across the three sites compared to farms without livestock. This is clear in the case of Zimbabwe where farms with medium to large herd sizes have higher farm net returns (See figure 6). However, about 80% of the population are extremely poor with poverty rates between 87% to 95%. In Senegal and Ghana, poverty rates between 65% to 92% demonstrate the already difficult situation under current conditions and no climate change. Food insecurity levels (i.e., the proportion of households that are food insecure) follows the same pattern as the poverty rates. The income-based food security (IBFS) indicator as described above, estimates the proportion of households that can't afford a nutritionally adequate food basket. The Cost of nutritionally adequate food basket (CoNA) was estimated for each country using data from the CANDASA project (https://sites.tufts.edu/candasa/), the Food Systems Dashboard (https://foodsystemsdashboard.org/) and other studies in each country.

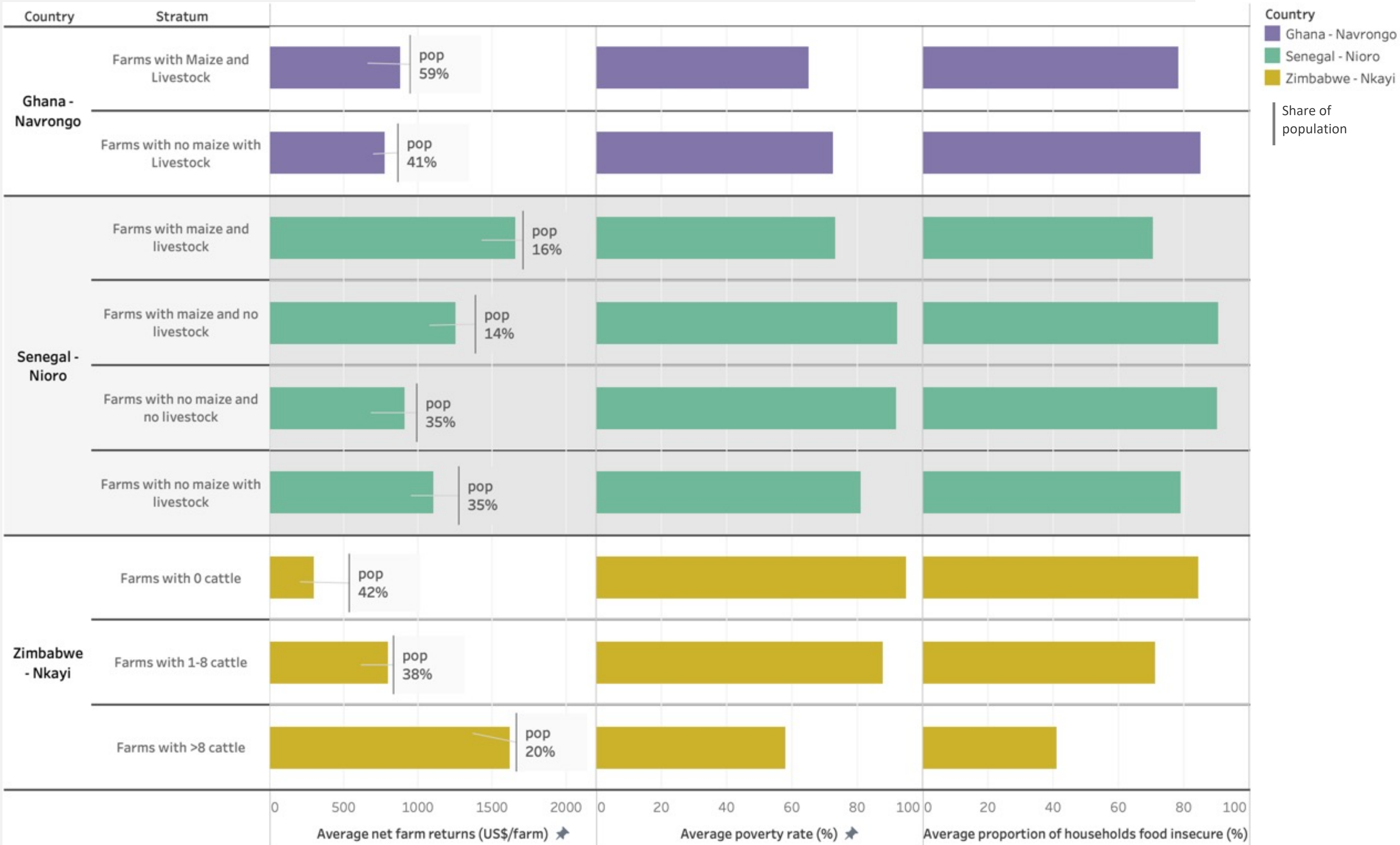

Figure 6. Current socio-economic conditions in Navrongo, Ghana; Nioro, Senegal and Nkayi, Zimbabwe: Average net farm returns, poverty rates and food insecurity by stratum. Share of population in each stratum is shown next to net farm returns,

IMPACTS OF AGRICULTURAL DEVELOPMENT PATHWAYS

The current conditions described in the previous section is of concern for stakeholders. The engagement with stakeholders demonstrated that there is awareness among stakeholders about these conditions and the risks associated with climate change. Every country has developed a set of plans, interventions and policies that have the objectives of achieving the Sustainable Development Goals (SDGs) by 2030-35. The pillar of the so called "Vision 2030" regarding the agricultural sector, is sustainable development. At the same time, the countries are developing their National Adaptation Plans and their Nationally Determined Contributions as part of their commitments for the UNFCCC Paris Agreement. While these processes have started several years ago, there is acknowledgement that proposed interventions, adaptation and mitigation strategies require science-based information that could inform decision makers about the possible consequences or impacts of these interventions or strategies on specific farming systems in each country.

The goal of the RAPs development is to capture the policies and interventions that could shape future conditions for the agricultural sector (e.g., 2030). Thus, the A-Teams used the countries' "Vision 2030" and related policy documents to develop a Sustainable Development Pathway. This pathway captured the key elements of the countries' plans for sustainable development. In addition, the NAP and NDCs processes were reviewed to capture climate policies and proposed adaptation strategies to test how these can offset impacts of climate change and make the farming system resilient to climate change.

Stakeholders also recognized that in the past, several efforts to implement the kinds of policies and interventions that would lead to improving smallholder farmers livelihoods towards achieving SDGs have failed or stayed stagnant. A Business as Usual pathway was developed to represent conditions if changes are not sufficient to improve current conditions to achieve the SDGs and improve farmers livelihoods. A third pathway called "Unsustainable Development" was developed with the goal of capturing the conditions where policies are meant to increase productivity rapidly in the short term but without consideration of environmental or socio-economic consequences in the long term.

Figure 7 shows the changes in average net farm returns from the current conditions to future conditions, with no climate change, under each pathway aggregated for every site. The results show that all three pathways lead to increasing the average farm net returns in the population. Consequently, poverty rates decrease compared to current conditions. For Senegal and Zimbabwe, the sustainable development pathway benefits more the population farms with larger increase in net farm returns and decrease in poverty rates. In Ghana, both the sustainable development and the unsustainable development pathways seem to provide similar benefits to farm households. In all three sites the BAU pathway results in lower benefits compared to the other two pathways making the case for the need to transform the agricultural systems. These results suggest that following and implementing the Vision 2030 that each country has developed may put them on track to improve conditions. However, as noted in figure 7, even in the cases where the pathways improve livelihoods, poverty rates are still high. Furthermore, disaggregated analysis (by strata) show that some pathways may increase inequality between the population of households in each site (see below).

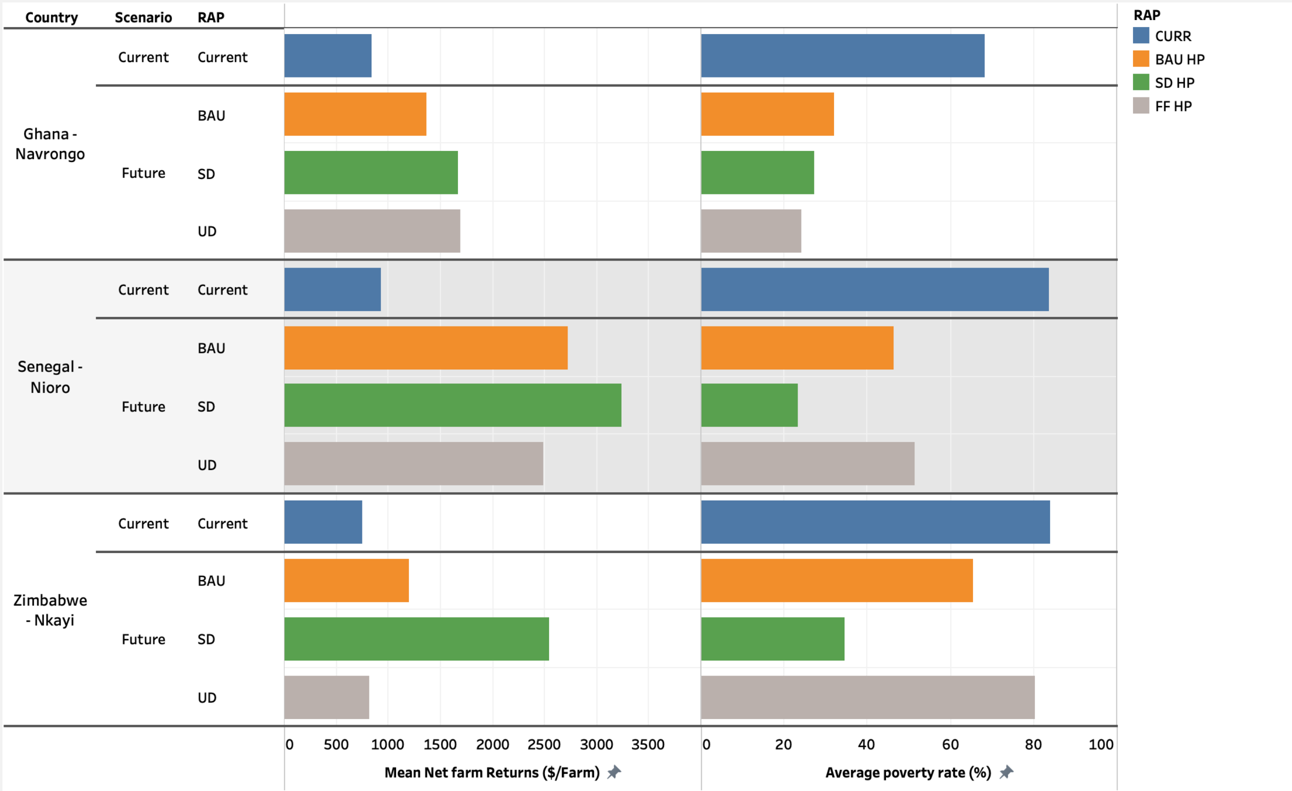

Figure 7. Agricultural development pathways: Population mean net farm returns (US$/farm) and poverty rate (%) under current and future conditions for each RAP. Aggregated results for High price scenario

IMPACTS OF CLIMATE CHANGE ON FARM NET RETURNS AND POVERTY RATES

The impact of climate change on crop yields described above and in Figure 5 show that in the three sites, groundnut would benefit from changing climate due to CO2 fertilization. Groundnuts contribution to farm net returns is significant, in particular in Ghana and Senegal. This situation and the fact that the impacts of climate change on the other crops in the system are small, result in increasing average net returns in the population of farms for Senegal under the 3 RAPs and for Ghana under the sustainable development RAP (See figure 8). Note that in Senegal, even under current conditions, climate change would increase farm net returns because of groundnuts. In the case of Zimbabwe, the aggregate results show that climate change causes losses under the three RAPs. Poverty rates decrease under the 3 RAPs in Senegal and under the SD RAP in Ghana. In the other cases, poverty rates increase but the magnitude is small. In the case of Zimbabwe, the aggregated result show that the poverty rates would increase with climate change. However, as discussed below, disaggregated results show that under some GCMs (e.g., Hot-

Wet) some strata may gain from climate change, but given that the gains are small, these results are lost in the aggregated results.

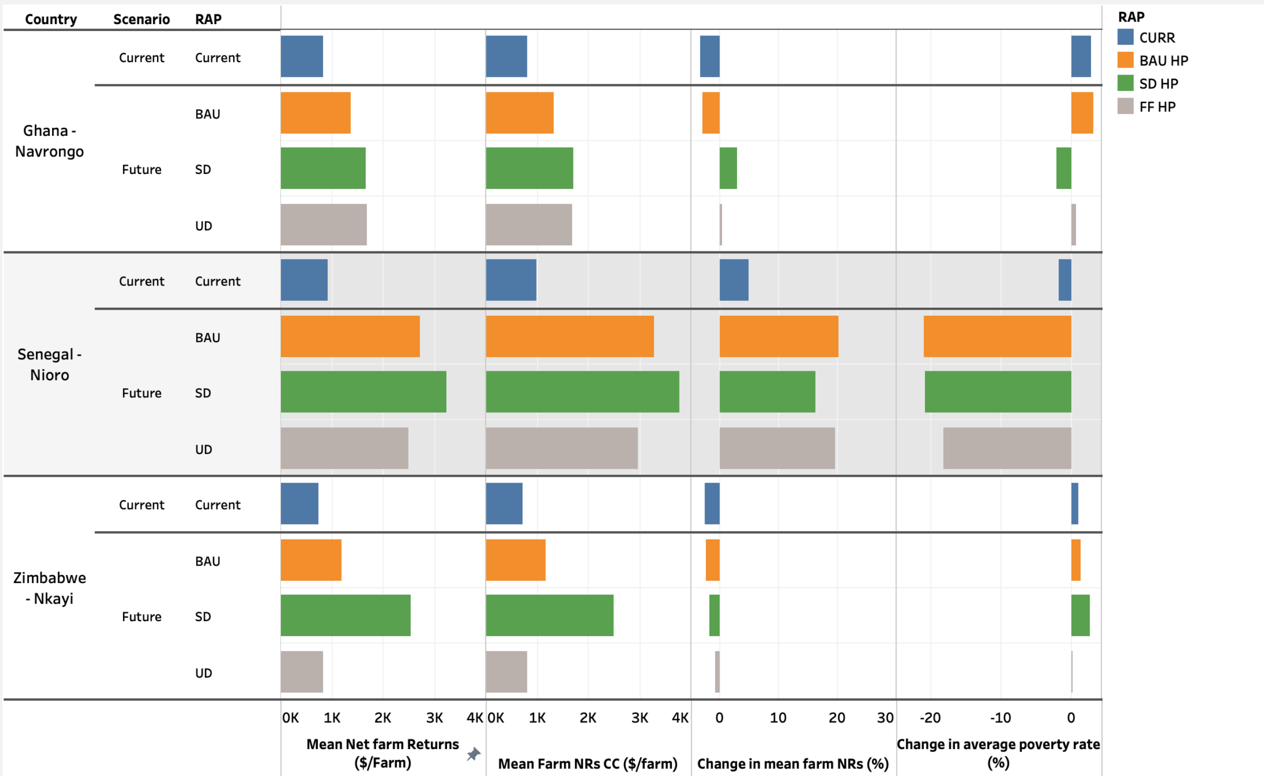

Figure 8. Climate change impacts on population mean net farm returns (US$/farm) and poverty rates. Aggregated results for each site.

VULNERABILITY, NET ECONOMIC IMPACTS AND POVERTY

The aggregated results described in the previous sections show that the combination of agricultural pathways and climate change in some cases can benefit smallholder farmers. This means that, in average, the gains are larger than the losses, so the net economic impact is positive. However, the results above need to consider the vulnerability of households under climate change. Figure 9 shows in the left panel and X-axis the net economic impact (NEI) as a proportion of mean net farm income and the y-axis shows the proportion of households that are vulnerable to climate change. The figure shows the results for all 3 countries by strata, GCMs and crop models. The current conditions (blue circles) show a range from losses (i.e., negative NEI) to gains (i.e., positive NEI). But in all cases, including the cases with gains, the proportion of farms that are vulnerable to climate change is high, between 35% to 85% of the population. Future conditions, under the RAPs seem to increase the range of negative and positive outcomes. While high NEI tend to decrease the vulnerability levels, a large proportion of households who gain from climate change are still at risk of losing income. The right-hand side panel shows the vulnerability-poverty relationship. As expected, increasing poverty rates lead to increased vulnerability. While the RAPs show to improve poverty rates, the levels of vulnerability can still be high is some scenarios.

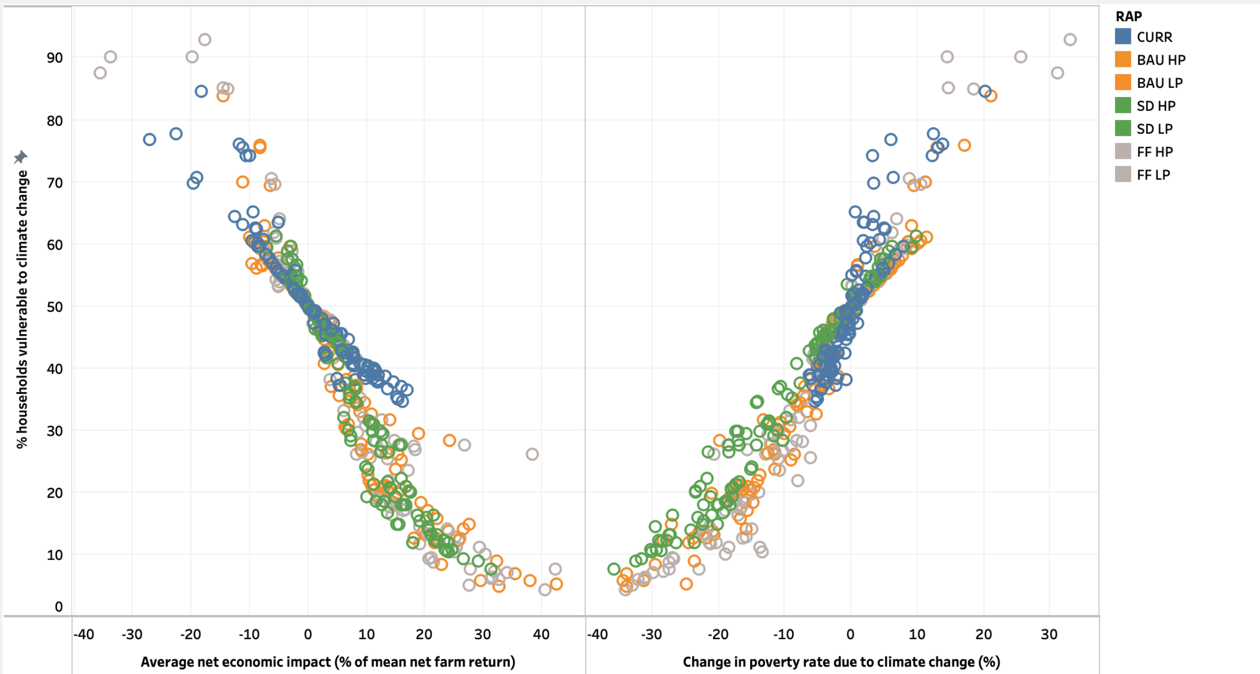

Figure 9. Vulnerability, net economic impact and poverty rates for Zimbabwe, Senegal and Ghana. Every point represents a stratum from each site under different GCM, crop model, RAPs and price ranges (low and high).

BENEFITS OF ADAPTATION STRATEGIES

The adaptation packages co-designed by the A-Teams and stakeholders were tested under the different RAPs showing an increase in the population mean net farm returns between 12% and 45% as shown in figure 10. The description of the adaptation packages can be found in the technical report and in tables 2-4 above. It is important to note that the Zimbabwe team developed three sets of adaptation packages under the sustainable development that involved different degrees of interventions and transformation of the farming system. Climate policies under the sustainable development enable the design of different levels of intervention and transformation which were not possible under the BAU and UD RAPs. The results show that the changes in net returns vary across RAPs, however the final outcome (e.g., poverty rates) would depend on the initial conditions with climate change. For example, in the case of Nioro, the adaptation under the BAU show higher increase of mean farm net returns compared to the SD and UD RAPs. However, because the farm income with climate change was lower under the BAU compared to the other RAPs, poverty rates are still higher than the SD case. In the Senegal and Zimbabwe cases, the sustainable development pathway creates higher benefits in terms of increased income and reduced poverty rates. Despite these positive improvements, the population average poverty rates remain between 14-20% in the best case. While this is a considerable improvement from the current conditions, the results suggest that earlier and perhaps more specific farming system transformation along with appropriate policies and investments are needed to achieve the SDGs and at the same time, create adaptation and mitigation interventions that reduce vulnerability and the associated socio-economic and environmental tradeoffs.

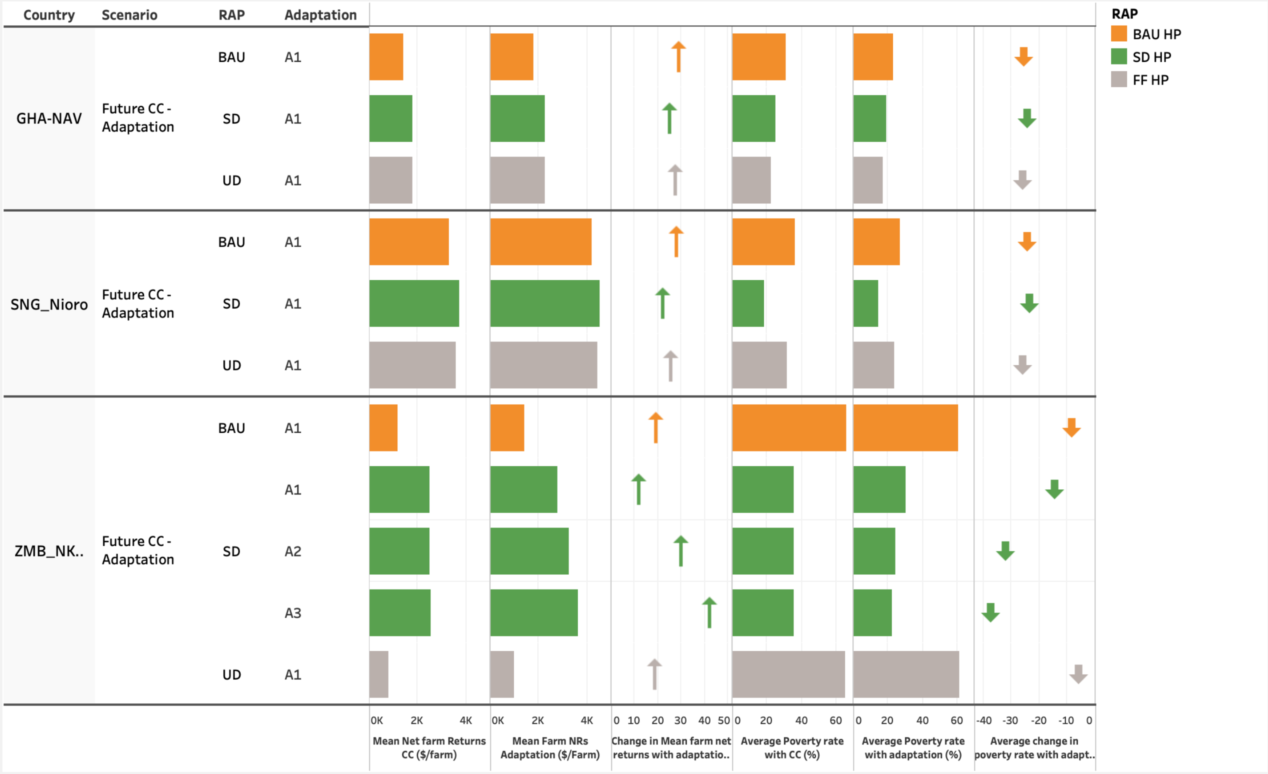

Figure 10. Benefits of adaptation packages under the three RAPs for each site. Aggregated results.

IMPACTS ON FOOD SECURITY

As described above, the IBFS indicator estimates the proportion of households that are food insecure (i.e., that can't afford the cost of a nutritionally adequate food basket). The current conditions show that food insecurity in the 3 sites is high, about 80% in Navrongo, Ghana; 82% in Nioro, Senegal and 69% in Nkayi, Zimbabwe. Figure 11 shows the changes in food insecurity for the 3 scenarios (simulation experiments described in table 1) and for the 3 sites. The first column shows the food insecurity for the base system in each simulation experiment. For the current and Future scenario, the first column is the food insecurity level with no climate change under current and future conditions respectively. In the case of the Future with climate change and adaptation, the first column shows the food insecurity with climate change and no adaptation. The second column shows the impacts of climate change on food insecurity for the current and future scenarios while the for the Future with climate change and adaptation, the second column is the food insecurity level with adaptation. The third column shows the % change in food insecurity for each scenario.

The results show that for Ghana and Zimbabwe, food insecurity may increase with climate change or some small gains can be achieved under the SD case. In the case of Nioro food insecurity can be reduced with the combination of the RAPs and climate change. However, it is with the adaptation packages that the 3 sites have the larger decrease in food insecurity. Like in the poverty rate case, in Zimbabwe and Senegal the SD RAP reduces the proportion of farms that are food insecure while in Ghana the UD and SD provide better benefits to households in Navrongo. Despite the improvements, the aggregate results show that there is still between 15% to 35% of households across the 3 cases that are food insecure.

Agricultural development can play a key role to decreasing food insecurity in these regions. For example, figure 12 shows the relationship between mean net farm returns and food insecurity. As expected, as income increases, food insecurity is reduced. The panel on the left shows the results for all sites while the panel on the right shows the results for Ghana. Under current conditions (blue circles) most of the scenarios show increasing food insecurity. Agricultural development pathways together with climate change can improve of worsen conditions. In Ghana, the BAU and UD seem to worsen conditions related to food insecurity, while the SD decreases food insecurity in almost all cases, however note that in this case the changes are small. What this means is that while the 3 RAPs on average and aggregated across strata and scenarios lead to increased farm net returns, the changes in food insecurity under climate change and RAPs could be negative for some cases (combination of drier climate projections and policies under the BAU and UD RAPs).

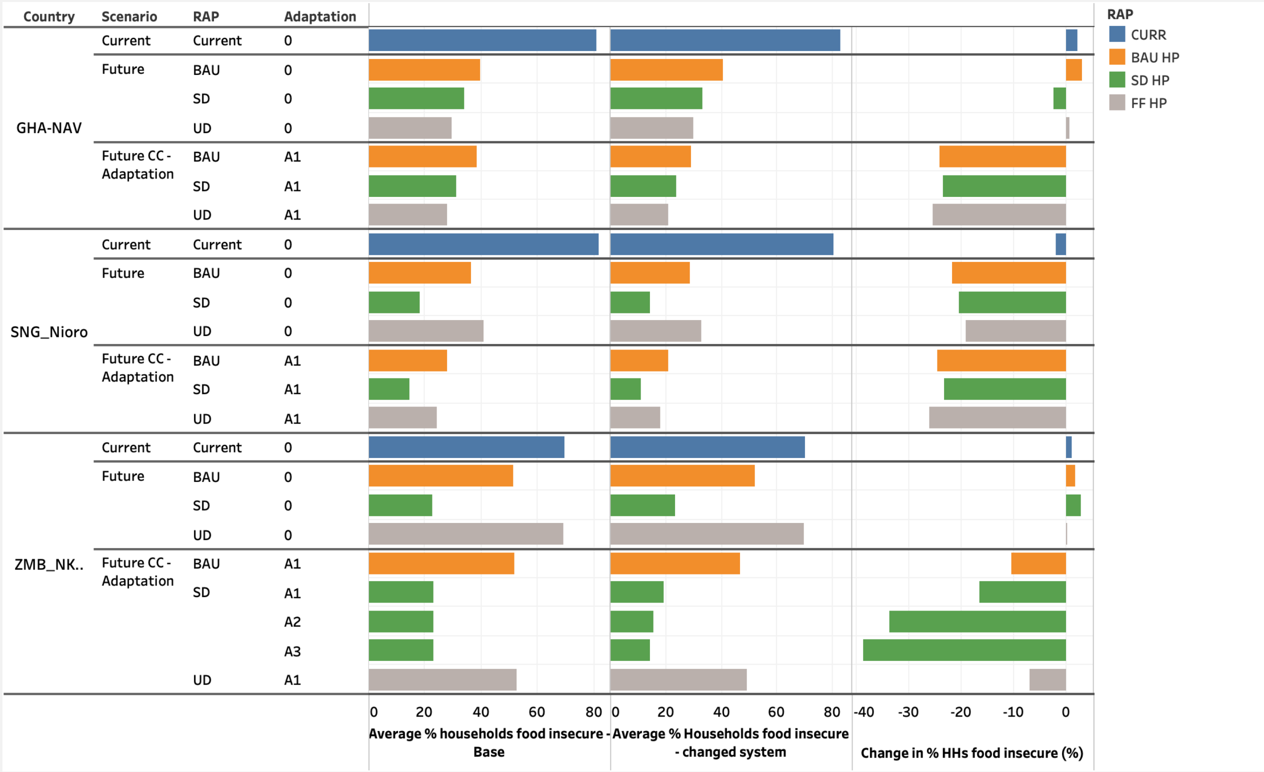

Figure 11. Food insecurity changes due to agricultural development, climate change and adaptations. Aggregated results for Navrongo, Nioro and Nkayi.

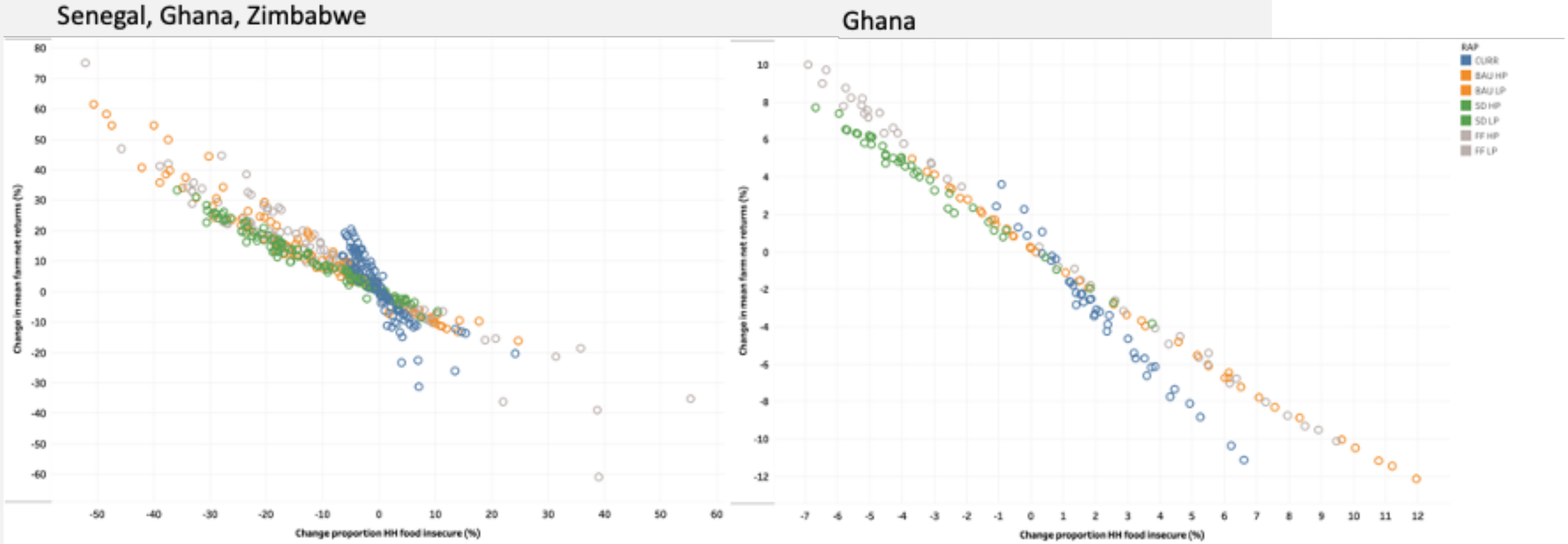

Figure 12. Changes in net returns and food insecurity: a. all sites, current and future (RAPs) b. Results for Navrongo, Ghana.

POVERTY AND INEQUALITY

The aggregated results discussed above show how from current conditions, characterized by low productivity and high poverty rates and food insecurity, agricultural development can improve these conditions and offset some of the loses due to climate change. While the magnitude of benefits from following each RAP are different, one could say that on average, any of the pathways could improve current conditions. However, the disaggregated results show that there are key tradeoffs associated to such gains that are critical for decision making.

This is the case of Nkayi, Zimbabwe for example. Figure 13 shows the poverty rates for each stratum on the top part of the figure. Under current conditions farms with no cattle have average poverty rates of about 95% while the stratum with medium herd size have poverty rate of 87% and the stratum with large herd size have a poverty rate of about 60%. The lower panel is a poverty gap indicator that indicates the average proportion of farm net returns in the population that is needed to be above the poverty line (i.e., to lifted out of poverty). Under current conditions households in the first stratum would need, in average, additional 55% of their farm net returns to be above the $1.25/person/day. The second strata needs to increase income by 40% and the third stratum by 25% as proportion of farm net returns.

Under future conditions, the SD RAP does a good job at lowering poverty rates across the 3 strata. Furthermore, the amount needed to be lifted out of poverty is low (about 13%) and similar for the 3 strata. However, under the BAU and UD pathways, the positive changes seem to benefit only to households with medium and large herd sizes. Figure 13 shows how in both RAPs, the first strata still have very high poverty rates while the other two strata benefit more, poverty rates are lower. In both cases the amount needed to be lifted out of poverty is considerably lower than the first strata. What this means is that both the BAU and UD have not only worsened conditions for the first stratum, but also have created a huge inequality among the population of households in Nkayi. This also has consequences under climate change and adaptation. As shown before, the results indicate that under these conditions, it is much difficult to support these farms. Implementation of adaptation packages would tend to fail or have a small response like the stratum 1 in Nkayi.

But what is more important and critical for stakeholders is to realize that under these pathways, a large proportion of the population may get worst off. Under current conditions, stratum 1 represented about 42% of the population of Nkayi, the second stratum 38% and the stratum with large herd size represented 20% of the population. Under the BAU pathway, the change on these shares is small, but between the second and first strata, they account for 78% of the population with poverty rates between 54% and 87%. In the UD case, things are worst. Changes in farm size, household size and other elements described in the RAPs have resulted in population increase in stratum 1. Under this pathway, stratum 1 now accounts for 66% of the population of Nkayi with poverty rates of 95%, while strata 3 only accounts for 12% of the population with poverty rates of about 45%. This inequality is perhaps an unintended consequence of the pathway, decision makers need to be aware of these possible outcomes, and the AgMIP-CLARE modeling approach can identify such issues.

On the other hand, the SD pathway seems to have reduced inequality across the 3 strata in Nkayi. While strata 1 still accounts for the larger share of population (40%) poverty rates are reduced more than half compared to current conditions and is similar to strata 2 poverty rate.

Under the SD pathway, climate policies and interventions enable the design and implementation of more complete adaptation packages, which led to better benefits to farmers.

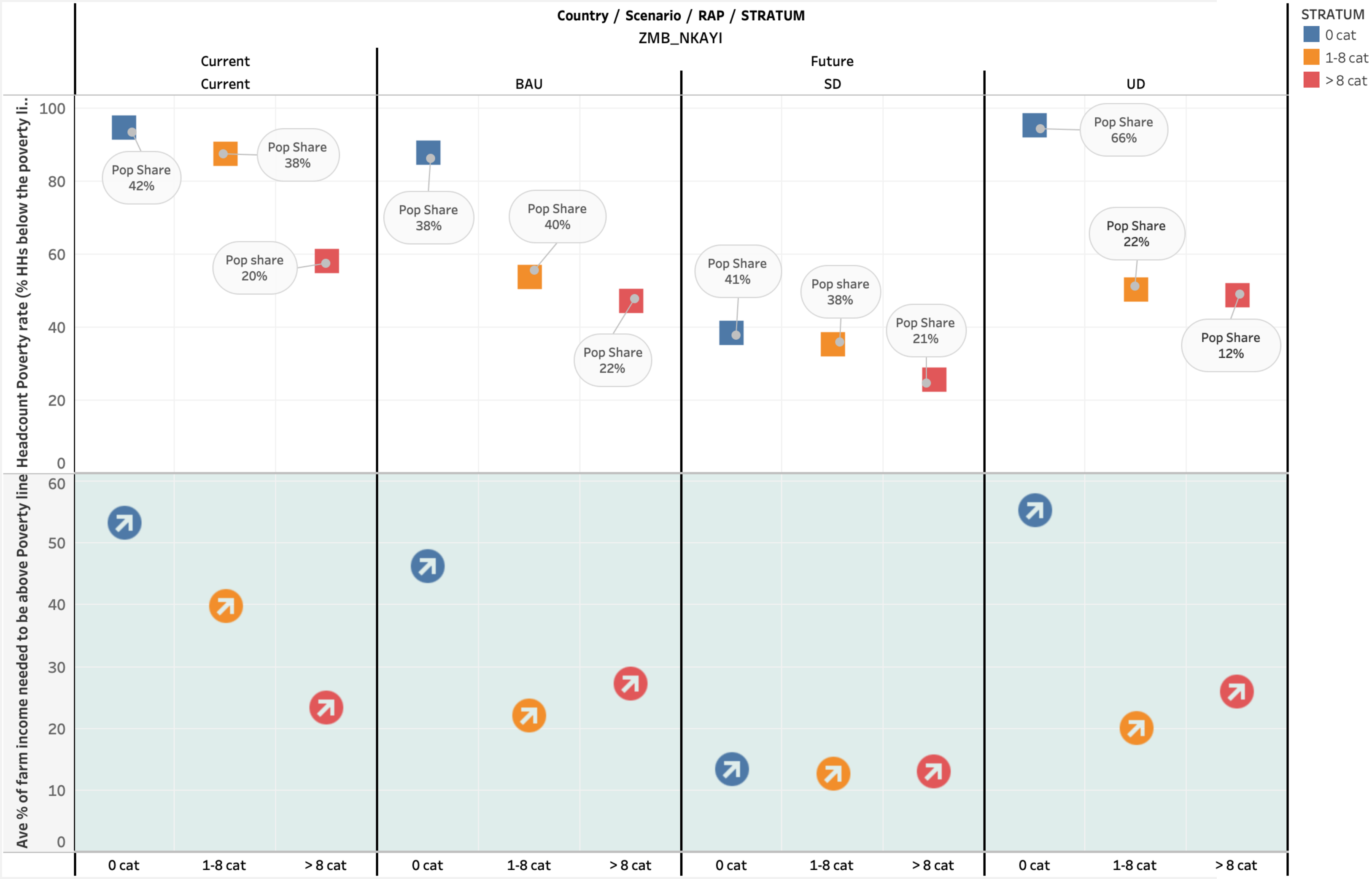

Figure 13. Economic impacts on poverty and inequality: The effect of agricultural development pathways on farm households.

AGRICULTURAL DEVELOPMENT, CLIMATE CHANGE AND ADAPTATION IMPACT ON SMALLHOLDER FARMERS: DISAGGREGATED SUMMARY

The data for Navrongo, Ghana was stratified in '*farms that grow maize and have livestock' (stratum 1)* and *'farms with no maize, with livestock' (stratum 2)*. The results show that both strata have similar average farm net returns and poverty rates and food insecurity levels (see figure 14). The explanation, in part, is that stratum 2 relies more on other cash crops like vegetables and peanuts, so the returns are comparable to stratum 1 farms that grow maize and have larger returns to livestock. Figure 15 shows the contribution of each activity in the farm to net farm returns. In the Navrongo case, peanut is the crop that contributes more to farm returns. While maize is also important in stratum 1, the joint contribution of the other crop activities and livestock is significant. Farm net returns in stratum 2 come mostly from vegetables and peanuts (about 60%). This diversification of activities has important implications for climate change and adaptation. However, productivity in all farm activities is currently low, hence average net farm returns are low which contributes to the extremely high poverty rates in the region. The average climate change impact on farm net returns is negative but small in both strata. Part of the explanation is that current low productivity does not allow for larger losses. In addition, as explained above, peanut's response to climate change is, in most cases, positive due to CO2 fertilization, which diminish the negative impacts on maize and other crop yields (e.g., vegetables). Investments on improved cultivars, access to inputs (e.g., fertilizers) and other policies such as the ones described in the Sustainable Development RAP could help making the system more resilient and in fact, the results show that agricultural development can contribute to decrease poverty rates and food insecurity. Figure 14 shows that under the SD pathway, the response of the system to climate change would yield positive benefits (i.e., increased net returns, decrease poverty rate and food insecurity). This is not the case if the BAU pathway is followed. The Fossil Fuel pathway shows small positive benefit compared to the SD pathway. The adaptation package tested for Navrongo results in further improvement of the system by increasing average net farm returns and decreasing poverty rates and the level of food insecurity in both strata as shown in Figure 16. Despite these positive outcomes, still about 20% of the population in each strata remain poor.

In the case of Nioro in Senegal, peanut production and climate change impacts on peanuts drive the results (Figure 15). The Nioro data was stratified by '*farms with no maize with cattle' (stratum 1); farms with no maize and no cattle' (stratum 2); 'farms with maize and with cattle' (stratum 3)*; and *'farms with maize and no cattle' (stratum 4)*. The high rates of poverty and food insecurity under current conditions are also caused by the low productivity of the system. Implementing policies and interventions for agricultural development would improve conditions, in particular if the Sustainable Development pathway is followed. Because of the large share of peanuts and millet to net farm returns in all 4 strata, the impacts of climate change are positive, poverty and food insecurity rates decline in all cases (Figure 14). However, the 2 strata with livestock are limited by the negative effects on livestock. The main effect of climate change on livestock production is through fodder. Feeding availability, in particular during drought conditions (or future conditions like the Hot and dry and Cold and dry scenarios) is a key determinant for livestock production. The adaptation package tested in this region involved improving cultivars, and in the cases with livestock, implementation of a climate smart livestock strategy was tested. The combined intervention results in further improvement of the farming system and farmers' livelihoods, especially in those strata with livestock (Figure 16).

The case of Nkayi in Zimbabwe included three strata. The first one for *'farms with no cattle';* stratum 2 included the *'farms with 1-8 cattle'* and strata 3 were the '*farms with more than 8 cattle'*. As with the cases of Nioro and Navrongo, the Nkayi region is characterized by low productivity (Homann-Kee Tui et al., 2021). However, in this case, farmers with large herd size are doing much better than farmers with no cattle or small herd size. Poverty rates in these two strata are between 88% and 95%, compared to 58% for the farms with large herd size. Stratum 1 depends heavily on maize, but the joint contribution of sorghum and peanuts to farm net returns is also important. While the three crops are also grown by farmers in strata 2 and 3, the relative importance of peanuts, sorghum and maize for farm net returns is much lower. Livestock contributes more than half of farm net returns in strata 2 and it constitutes about 80% of farm net returns in strata 3 (Figure 15). Agricultural development (i.e., RAPs) in this case shows contrasting results (Figure 14). Implementing policies and interventions can lead to improving conditions for a sector of the population, but it could also make it worse (or at least not improving) for others. The previous section about poverty and inequality showed the case of Nkayi in detail. RAPs that do not consider the local context and needs to support agricultural transformation like the policies and interventions under the BAU and Unsustainable Development pathways can increase inequality in the region. These two pathways show improvement for the farmers with cattle (strata 2 and 3) while strata 1 is stuck with high poverty rates. It is only under the Sustainable development pathway that all 3 strata improve livelihoods (higher net farm returns, lower poverty and food insecurity rates) while at the same time, create the opportunity for reducing the inequality gap, in terms of poverty and food insecurity (Figure 14), The adaptation interventions tested for Nkayi under the UD and BAU cases seem to improve conditions only for farmers with large herds. Farmers in strata 1 are stuck with high poverty rates and low productivity which make the adaptation strategy ineffective. Contrary to this, the Sustainable development pathway created the conditions to test a set of adaptations aimed at reducing the tradeoffs and improving farmers livelihoods. The adaptation strategies under the SD pathway (A1-A3 in figure 16; see also Table 3 for details) show that they are effective at improving farmers livelihoods but also at reducing the inequality in the region. Poverty and food insecurity rates decrease in all 3 set of interventions, but it is in A3, which include crop and livestock diversification, where farmers livelihoods improve the most. However, potential tradeoffs between socio-economic and environmental outcomes (e.g. GHG emissions) need to be addressed. This is discussed in the next section.

The results described in this section and in Figures 14-16 are aggregated across GCMs, the two crop simulation models and high and low-price ranges. See the appendix for figures that include all disaggregated results.

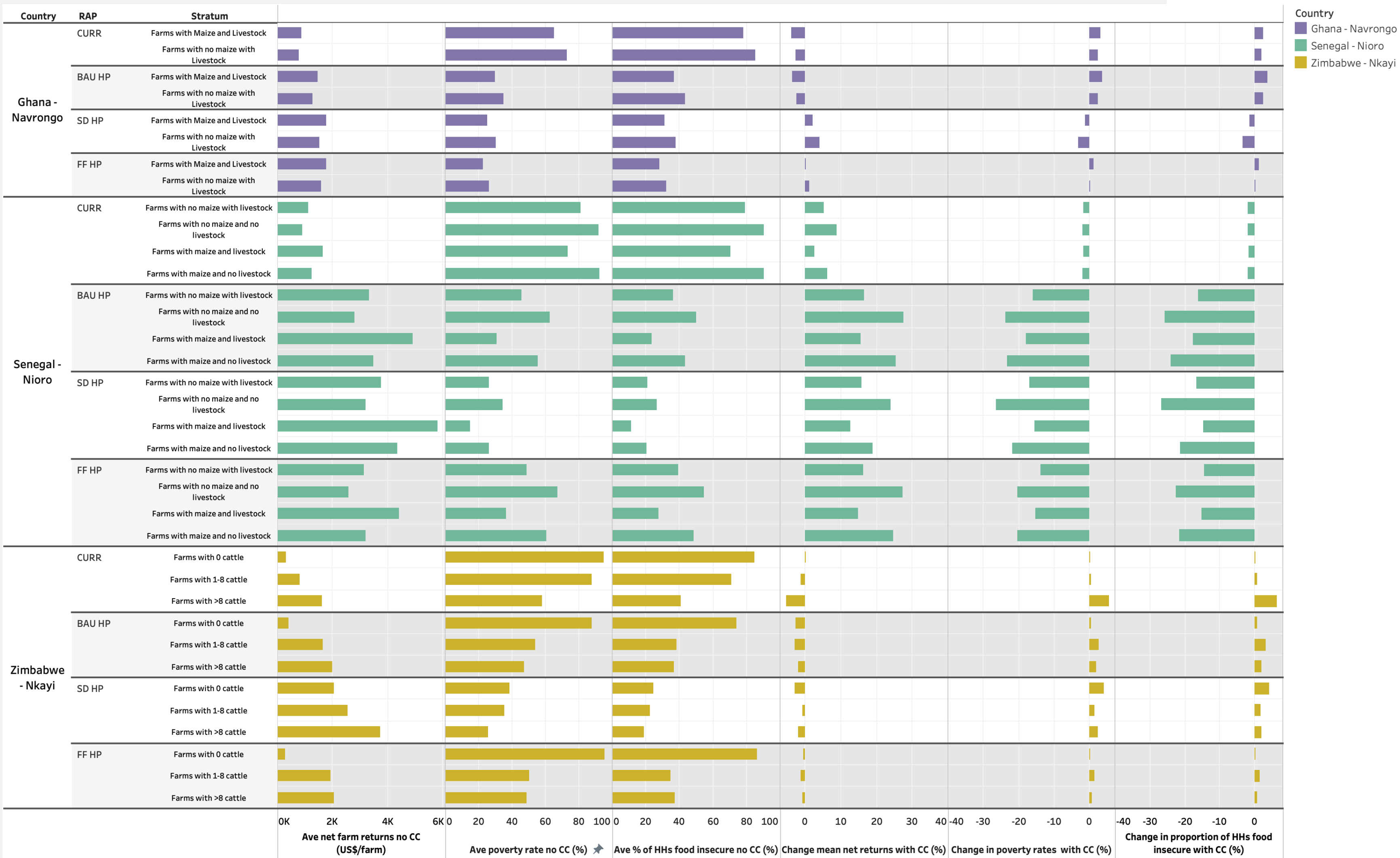

Figure 14. Average farm net returns, poverty, and food insecurity rates under current and future (RAPs) conditions with and without climate change for Navrongo, Ghana; Nioro, Senegal and Nkayi, Zimbabwe by strata. Results aggregated across GCMs, crop simulation models and high-low price ranges.

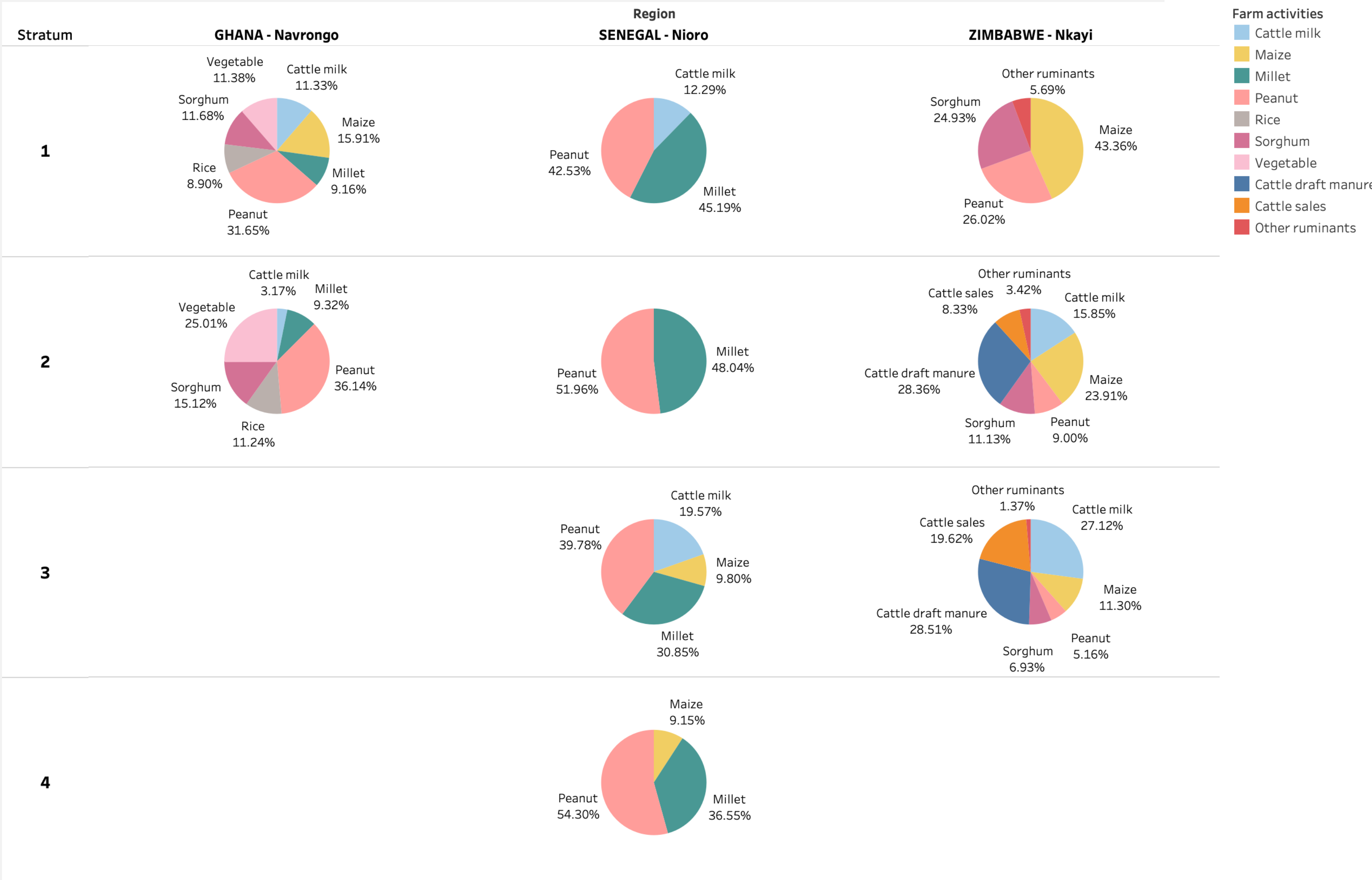

Figure 15. Contribution of each farm activity's net returns to total farm net returns by strata for Navrongo, Ghana; Nioro, Senegal and Nkayi, Zimbabwe under current conditions. See text for strata definition.

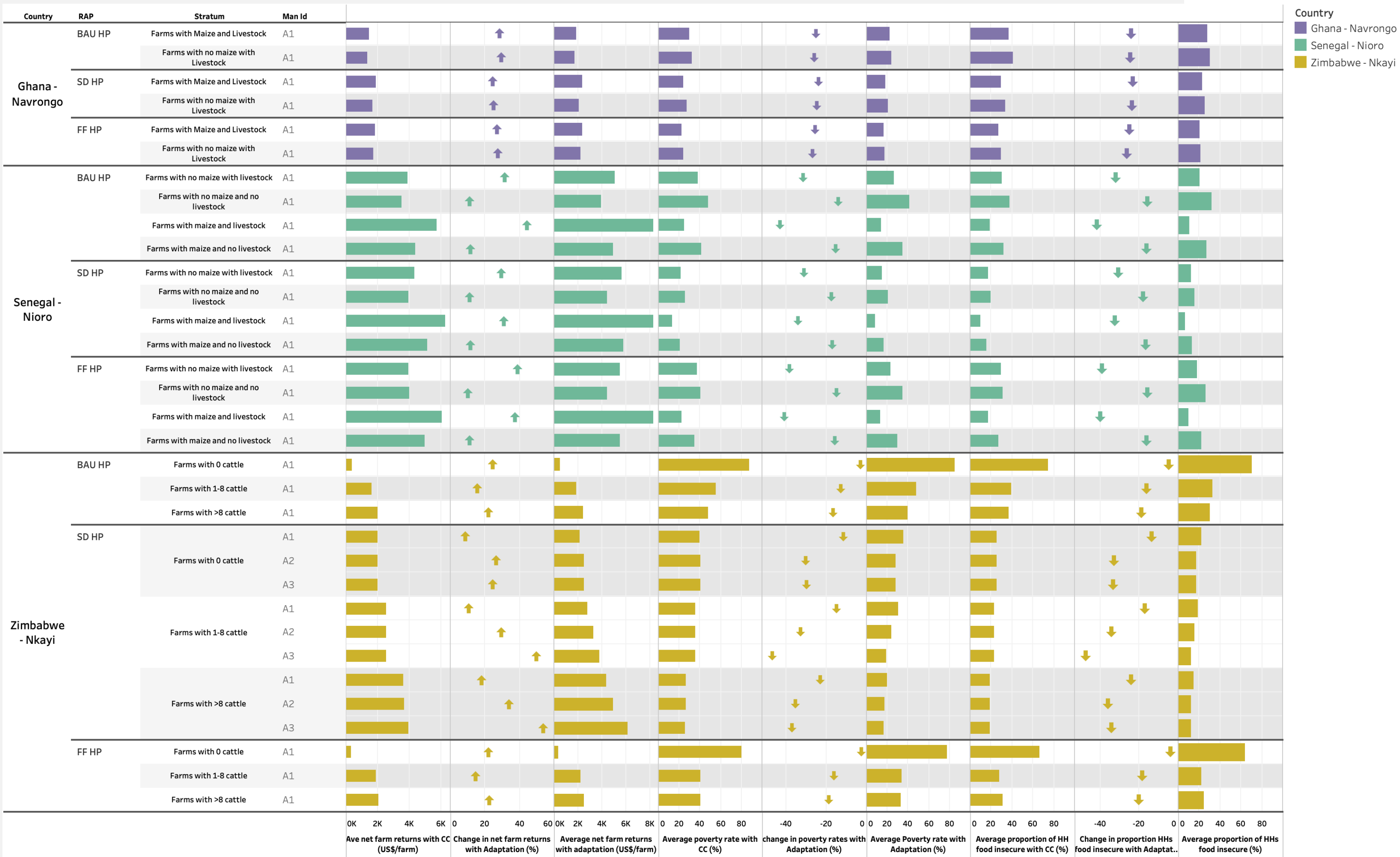

Figure 16. Impacts of adaptation packages on farm net returns, poverty, and food insecurity rates by strata for Navrongo, Ghana; Nioro, Senegal and Nkayi, Zimbabwe. Results aggregated across GCMs, crop simulation models and high-low price ranges.

ENVIRONMENTAL IMPACTS: ASSESSING ADAPTATION-MITIGATION CO-BENEFITS

Given the importance of livestock in Zimbabwe, and the increasing interest by stakeholders in promoting livestock smart alternatives that contribute with the country's mitigation goals (e.g. NDCs), the potential co-benefits of adaptation and mitigation were evaluated for Nkayi. This section presents preliminary results. Figure 17 shows that, for all scenarios tested, methane (CH4) from enteric fermentation is the largest contributor to GHGs followed by direct nitrous oxide (N20) fluxes from soil and methane from manure.

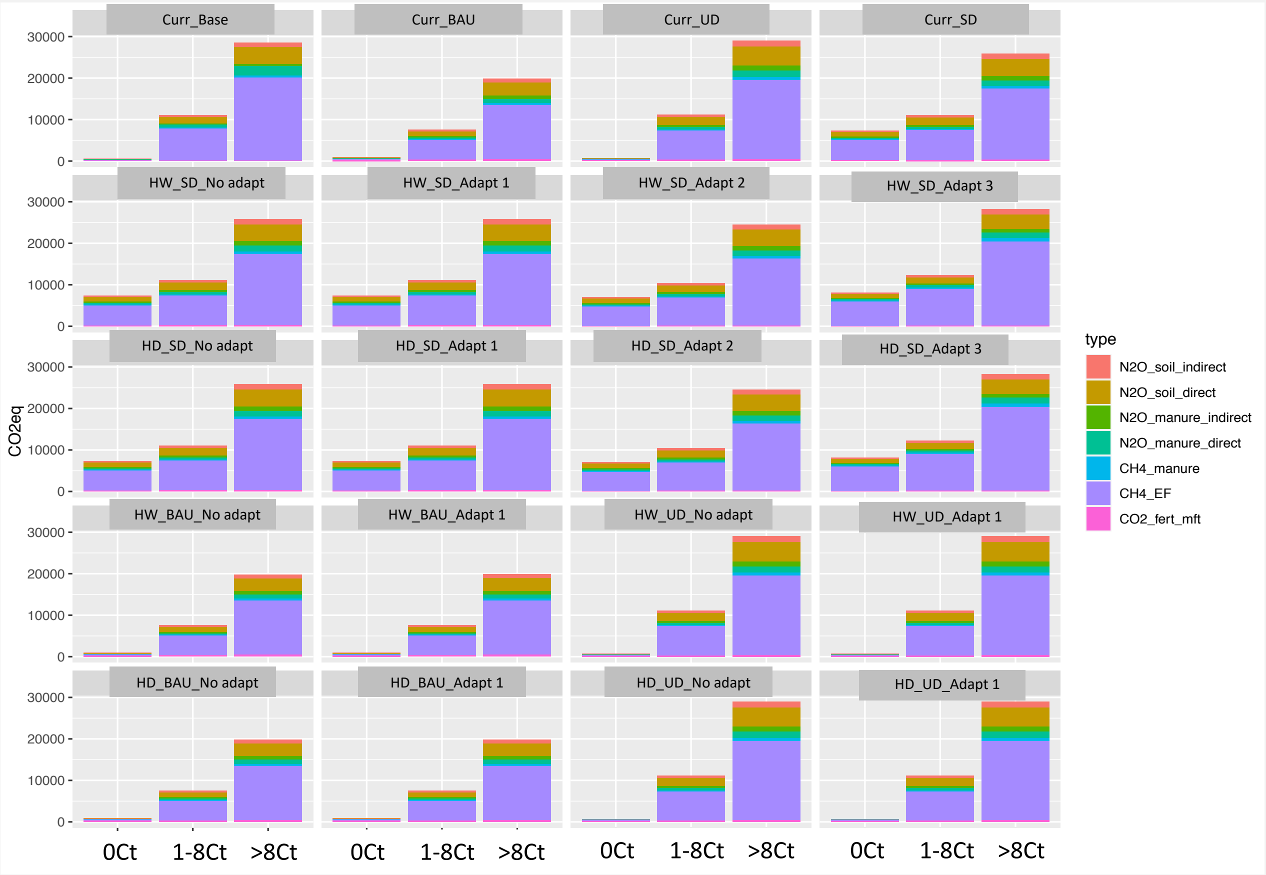

Figure 17. Estimated GHG emissions under current and future conditions (3 RAPs), climate change impacts and adaptations by farm types in Nkayi, Zimbabwe. HW=Hot-Wet climate; HD=Hot-Dry climate; Curr=Current conditions, no climate change; BAU=Business as Usual; SD=Sustainable Development; UD=Unsustainable development; Adapt x=Adaptation packages, x=1,2,3; No adapt=climate change and no adaptation. Preliminary results.

The adaptation packages under the Sustainable development pathway were designed to assess possible adaptation-mitigation co-benefits. The adaptation package A1 included switching to drought tolerant varieties, the adaptation A2 added improvements for livestock feed supply and introducing leaucaena into the cropping system. The third adaptation package A3, builds from the previous but with the goal of switching cattle to goats (See table 4 for details). In order to assess the contribution of the farm activities to total Greenhouse emissions (GHGs), different sources of emissions were estimated for the different scenarios. Figure 18 shows the estimated GHG emissions aggregated by stratum and climate scenarios for future conditions (SD) with climate change.

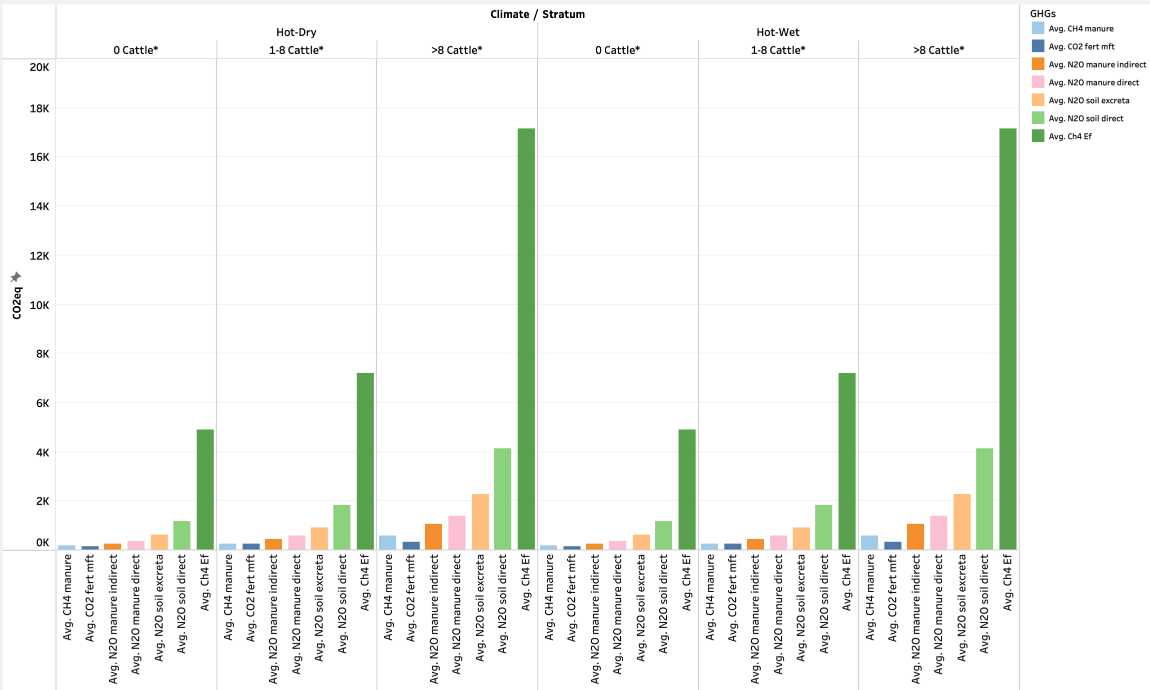

Figure 18. Estimated GHG emissions for Nkayi, Zimbabwe under future conditions (SD pathway) and with climate change. Results are aggregated by climate scenario and stratum.

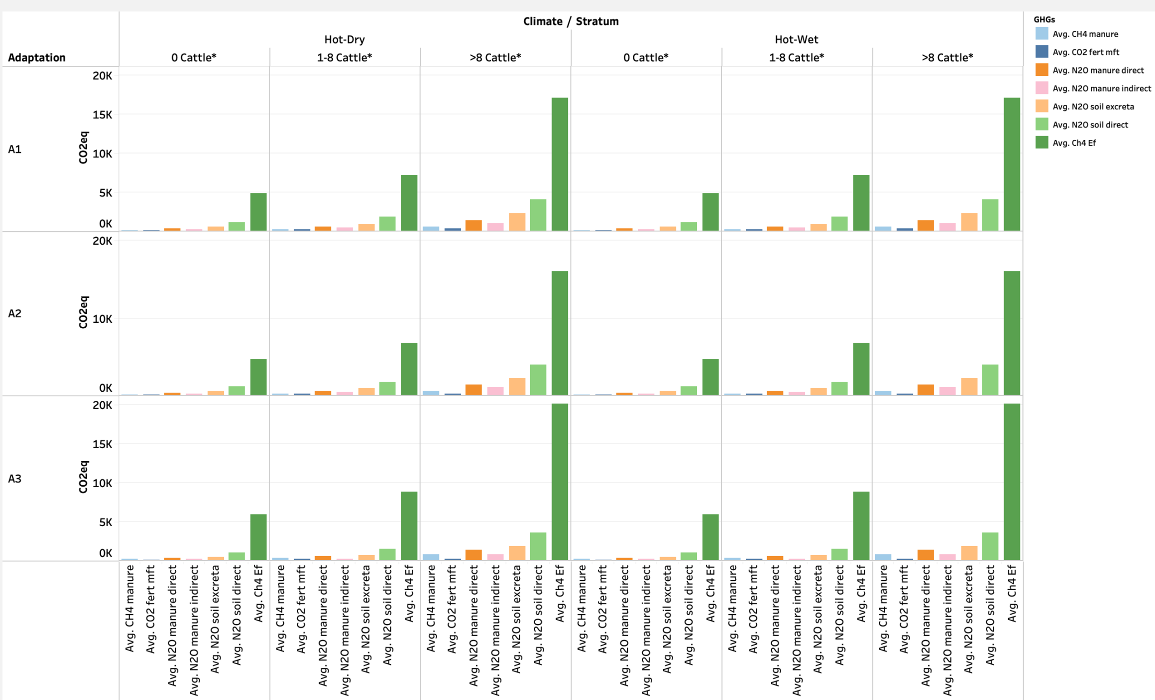

Figure 19. Estimated GHG emissions for Nkayi, Zimbabwe under future conditions (SD pathway) and with climate change adaptations. Results are aggregated by climate scenario and stratum. * The farm type labels correspond to the characteristics of the farms before adaptation. The adaptation packages increase herd sizes across the population, including farms that did not have cattle before.

The adaptation package as defined above include elements aimed at improving feeding availability while at the same time improving soil health. This included changes in land allocation and introducing a high yielding tree, Leucaena. The estimated GHGs under these scenarios are shown in Figure 19. Methane from enteric fermentation, and nitrous oxide from soils seem to be the largest contributors to GHGs emissions. The lower emission levels from farms in strata 1 are caused by the small herd sizes on these farms, compared to strata 2 and 3.

Figure 20 shows the tradeoffs between the difference in farm net returns and the estimated changes in methane emissions from enteric fermentation and in the total GHGs emissions for each farm, if they were to switch to one of the adaptation packages. The adaptation package one (A1) is based on improving cultivars with little implication for livestock and emissions, that is why the almost vertical blue points in the figures. The difference in GHG emissions across the strata is substantial but expected due to the larger herd sizes in strata 2 and 3. Tradeoffs between farm net returns and GHG emissions means that increasing net returns may increase GHG emissions and vice versa as shown in figure 20. However, in the case of adaptation package A2, there are some farms that would decrease GHG emissions while also increase net farm returns. The NW quadrant represents the win-win outcomes (increasing net returns while decreasing GHG emissions). The SW quadrant shows a lose-win situation, where GHGs are reduced at the expense of reducing net farm returns. The SE quadrant is the worst-case scenario or lose-lose situation where GHGs are increased while net returns decrease. The NE quadrant shows the win-lose case where net farm returns increase at the expense increasing emissions. The results suggest that pushing farmers to adopt the adaptation package 3 (AP3) may increase emissions substantially, however, as described above, farmers livelihoods would improve (i.e., poverty rates and food insecurity will decrease). AP2 on the other hand may provide win-win conditions for some farms, but there are farms that may also lose. The previous analysis assumes that every farm would switch to the adaptation package. The TOA-MD model was used to assess the potential adoption rates for each adaptation package and the socio-economic and environmental impacts associated to that adoption. Methane from enteric fermentation and the total GHG emissions were used in the analysis to test the mitigation effects. For this preliminary assessment only results from APSIM were used.

Results from this analysis are summarized in Table 6. Adoption rates for the adaptation package one (A1) range between 45% to 55% across the two GCMs while adaptation packages A2 and A3 have much higher adoption rates (73% - 94%). Impacts on socio-economic outcomes have been discussed in detail in previous sections, in all cases farm net returns increase and poverty rates decrease. What is important to note is the magnitude of the impacts, adaptation packages A2 and A3 provide larger increases in net returns and do a better job decreasing poverty rates. The environmental impacts show that adopting A1 would result on a small increase in methane emissions and overall GHGs. This small increase, between 1% to 2%, is expected because the adaptation package is focused on improving cultivars and have small effect on livestock production. The adaptation package A2, on the other hand shows a decrease in emissions. This suggests that improving livestock feed availability and quality could transform the income-GHG tradeoffs in win-win outcomes. High adoption rates of this adaptation package indicates that a large proportion of the farmers population in the region would benefit from the adaptation while contributing to mitigate emissions. The A3 adaptation package transforms the livestock system by switching cattle to goats. The results show that GHG emissions increase substantially with this adaptation strategy, but also provided much higher benefits in terms of increasing net farm returns. Part of the explanation for the high increase in emissions is that in the design of the adaptation package, it was assumed that farmers may need to convert from cattle to goats maintaining the same level of TLU (Tropical Livestock units), therefore, farmers ended up with a large goat herd size. Additional analysis or sensitivity analysis is needed to test how tradeoffs can be minimized or changed to synergies. Other benefits that may provide this adaptation package (e.g., benefits to women and youth) have not been captured in this analysis.

These results raise the questions about how to implement adaptation strategies, what outcomes become more important for policy decision makers and if the adaptation strategies should be implemented in the same way for all farms (i.e., for all farm types) and what information is needed to design adaptation and mitigation strategies. Using these preliminary results, figure 21 shows the possible pathways for implementation of adaptation-mitigation strategies and the associated tradeoffs. Clearly, if increasing income (and reducing poverty, etc.) is the priority, then A3 would be the preferred option. This might be the case if the potential gains from mitigation are small and the contribution to the overall mitigation efforts of the country is not significant. However, if environmental benefits are part of the priority, then A2 would be the best alternative, at the expense of lower economic gains. However, even in the case where A3 is the preferred alternative, not all the strata respond the same way. In fact, for stratum 1 the adaptation A2 would be the best option in all cases compared to strata 2 and 3. While adoption rates for the A2 package are already high, in this and other cases where there is the need to increase adoption, other programs that incentivize adoption, such as payments for eco-system services, might be needed.

While the preliminary results of this study are focused on a small region in Zimbabwe, the analysis above have important implications for the design and implementation of adaptation-mitigation strategies. Furthermore, it shows the kinds of information that AgMIP-CLARE can produce to support policy decision making.

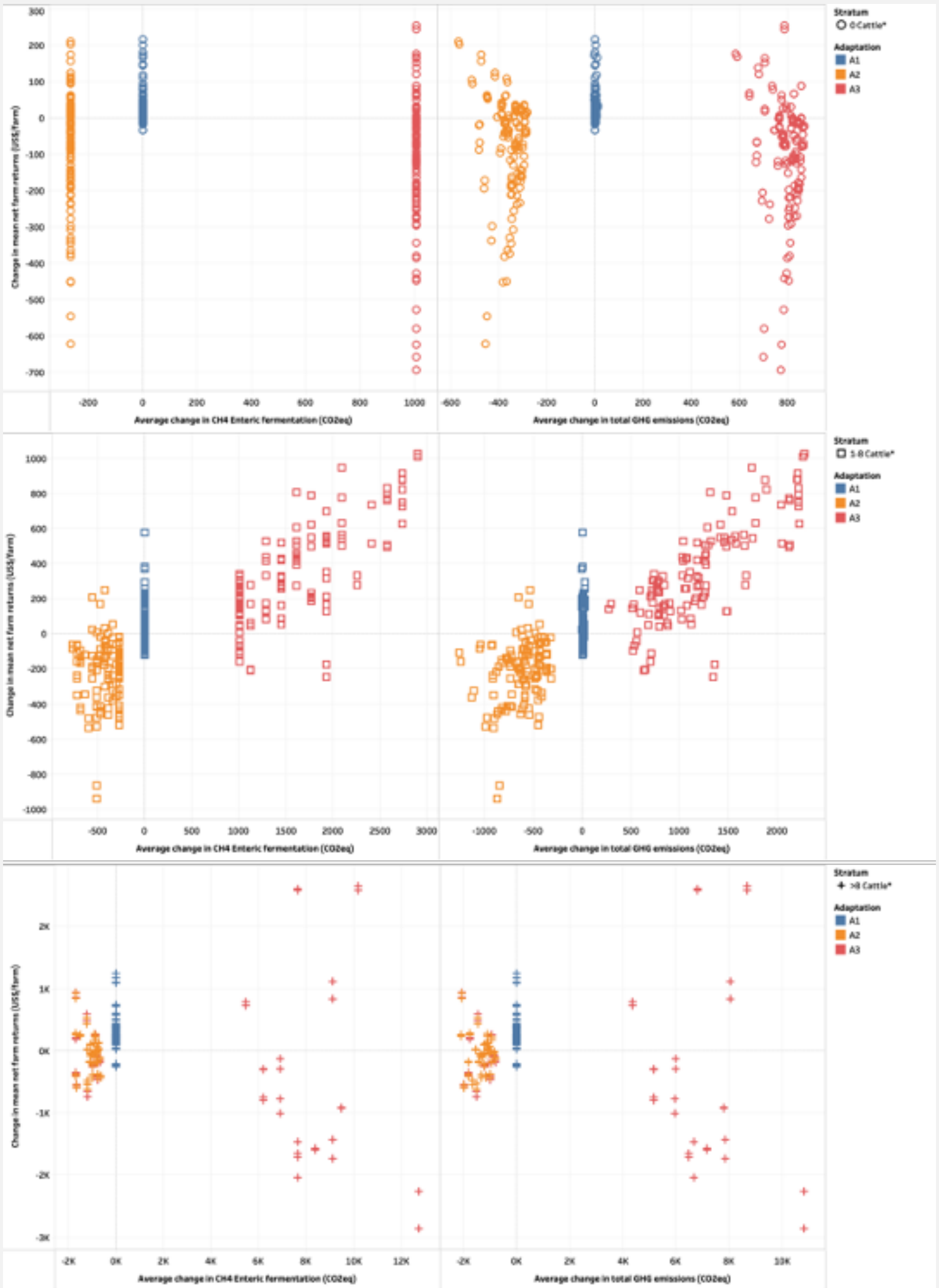

Figure 20. Change in farm net returns and methane emissions from enteric fermentation and total GHG emissions if farmers were to adopt the adaptation packages for the 3 strata in Nkayi, Zimbabwe.

Table 6. Adoption of proposed adaptation packages and impacts on socio-economic and environmental outcomes in Nkayi, Zimbabwe.

Climate	Adaptation	Stratum	Adoption rate (%)	MNR_CC (US$/farm)	MNR_Adapt (US$/farm)	Change in net farm returns (%)	Pov rate CC (%)	Pov rate Adapt (%)	Change in pov rates (%)	CH4 Eff CC (CO2eq)	CH4 Eff Adapt (CO2eq)	Change in CH4 Eff (%)	Tot GHG CC (CO2eq)	Tot GHG Adapt (CO2eq)	Change in Tot GHG (%)
Hot - Dry	**A1**	0 Cattle*	54	1,967	2,132	8	41	36	-11	4,900	4,967	1	7,385	7,499	2
		1-8 Cattle*	45	2,386	2,571	8	39	35	-11	7,218	7,277	1	11,057	11,190	1
		>8 Cattle*	55	3,401	4,007	18	28	22	-22	17,132	17,254	1	25,820	26,060	1
	A2	0 Cattle*	87	1,967	2,502	27	41	28	-30	4,900	4,687	-4	7,385	7,120	-4
		1-8 Cattle*	80	2,386	3,034	27	39	27	-29	7,218	6,918	-4	11,057	10,652	-4
		>8 Cattle*	77	3,414	4,626	36	28	18	-36	17,131	16,436	-4	25,819	25,002	-3
	A3	0 Cattle*	89	1,967	2,465	25	41	29	-30	4,900	5,819	19	7,385	8,144	10
		1-8 Cattle*	94	2,387	3,546	49	39	21	-45	7,218	8,786	22	11,057	12,295	11
		>8 Cattle*	83	3,731	5,775	55	28	17	-38	17,303	19,727	14	26,081	28,177	8
Hot - Wet	**A1**	0 Cattle*	51	2,007	2,166	8	40	35	-11	4,900	4,964	1	7,389	7,498	1
		1-8 Cattle*	52	2,627	2,894	10	34	29	-15	7,218	7,298	1	11,063	11,225	1
		>8 Cattle*	53	3,771	4,422	17	25	20	-22	17,133	17,287	1	25,828	26,101	1
	A2	0 Cattle*	86	2,007	2,518	25	40	28	-29	4,900	4,695	-4	7,389	7,135	-3
		1-8 Cattle*	82	2,627	3,373	28	34	23	-32	7,218	6,924	-4	11,063	10,658	-4
		>8 Cattle*	73	3,783	5,007	32	25	17	-34	17,131	16,490	-4	25,827	25,071	-3
	A3	0 Cattle*	87	2,007	2,482	24	40	28	-29	4,900	5,800	18	7,389	8,136	10
		1-8 Cattle*	93	2,628	3,890	48	34	18	-46	7,218	8,789	22	11,063	12,307	11
		>8 Cattle*	81	4,089	6,221	52	25	16	-35	17,288	19,683	14	26,046	28,115	8

* *Farm types are labeled based on the current characteristics of the farms, future conditions change due to changes in land allocation and increased herd size, including the strata with no cattle. Outcome indicators are population means: MNR=farm mean net; Pov rate=Headcount poverty rate; CH4 Eff=methane emissions from enteric fermentation; Tot GHG= Total GHG emissions (including CH4 and N20 from different sources); CC=under climate change; Adapt=with adaptation.*

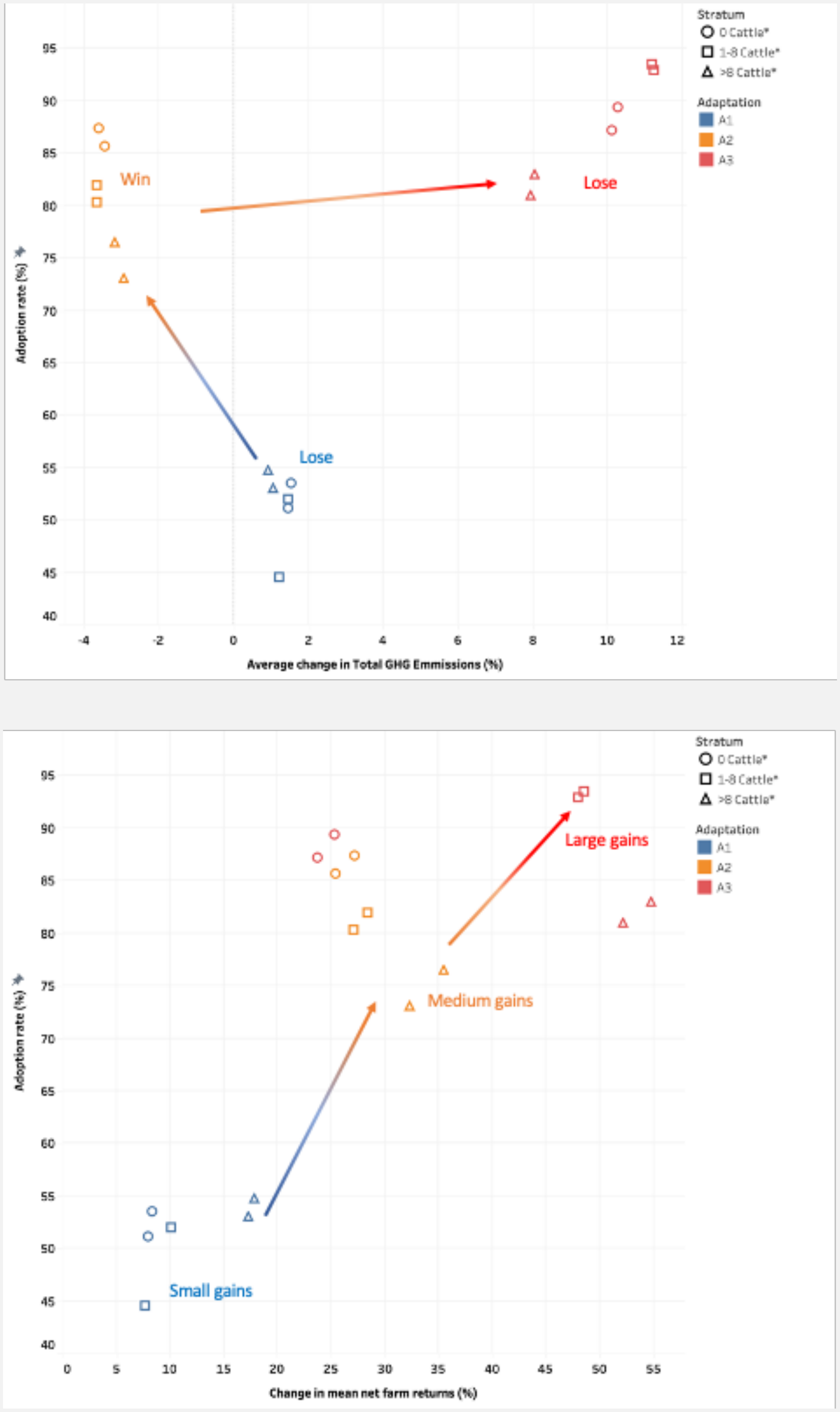

Figure 21. Pathways to win-win socio-economic and environmental outcomes.

KEY FINDINGS: SUMMARY

- Current conditions in the 3 sites show low productivity and low farm income leading to high poverty rates and food insecurity.
- Climate change may impact differently to farms. Hot and dry, and cold and dry climate scenarios have higher negative impacts on crop and livestock yields. Hot and wet climate scenarios may increase yields of some crops.
- The magnitude of climate impacts also depends on how farmers manage their crops (e.g., input use quantities) and other bio-physical conditions (e.g., soil fertility).
- CO2 fertilization can play a key role on crops like groundnuts that benefits from climate change, in particular if these crops have a large share of total farm returns.
- Even in cases with positive impacts of climate change (i.e., average net gains) vulnerability, poverty and food insecurity rates remain high.
- Agricultural development based on policy and interventions that consider both, national goals and local (sub-national) needs, can improve farmers livelihoods with no climate change, and help to offset negative impacts of climate change.
- The Sustainable Development pathway tested in the 3 countries showed to provide higher benefits to farmers and make the system more resilient to climate change: increase farm net returns, decrease poverty and food insecurity rates while decreasing inequality among the population of farmers in these regions.
- Agricultural pathways may have different effects of different types of farms. Thus, development of the RAPs capturing the heterogenous conditions of the population of farms in a region was key to assess impacts by strata, but also to co-develop with stakeholders, adaptation packages that could be considered as priority by the government's National Adaptation Plan process and at the same time, relevant and context-specific for the farming systems being studied.
- Adaptation packages tested in this project, may benefit farmers by increasing farm net returns, decreasing poverty rates and food insecurity levels.
- Adaptations that are based on a single strategy (e.g., use of improved cultivars, change of planting dates, etc.), are not enough and in some cases may even cause negative impacts. Adaptation packages need to include interventions or policies that would enable and motivate the adoption and success of the proposed strategies (e.g., access to input and output markets).
- However, if agricultural development fails to improve farming system conditions through policies and interventions (e.g., improving soil fertility), the benefits of adaptations might be small, or in some cases could increase inequality within a population of farmers in a region.
- Environmental, socio-economic, and bio-physical tradeoffs need to be considered in the design of policies and interventions aimed at maximizing adaptation-mitigation co-benefits.
- Mitigation strategies might need to be promoted with incentives to increase adoption (e.g. payment for eco-system services) where tradeoffs are difficult to overcome.
- The AgMIP-CLARE results suggest that understanding the response of farming systems to both national policy and technological interventions as well as climate change, requires a good assessment and understanding of the farming systems at the local (sub-national) level. The AgMIP-CLARE approach to assess climate change and adaptation impacts can result on science-based information to support the design of policies at national level, and interventions targeted to specific farming systems, while at the same time contribute with processes like the NAPs and NDCs.

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APPENDIX

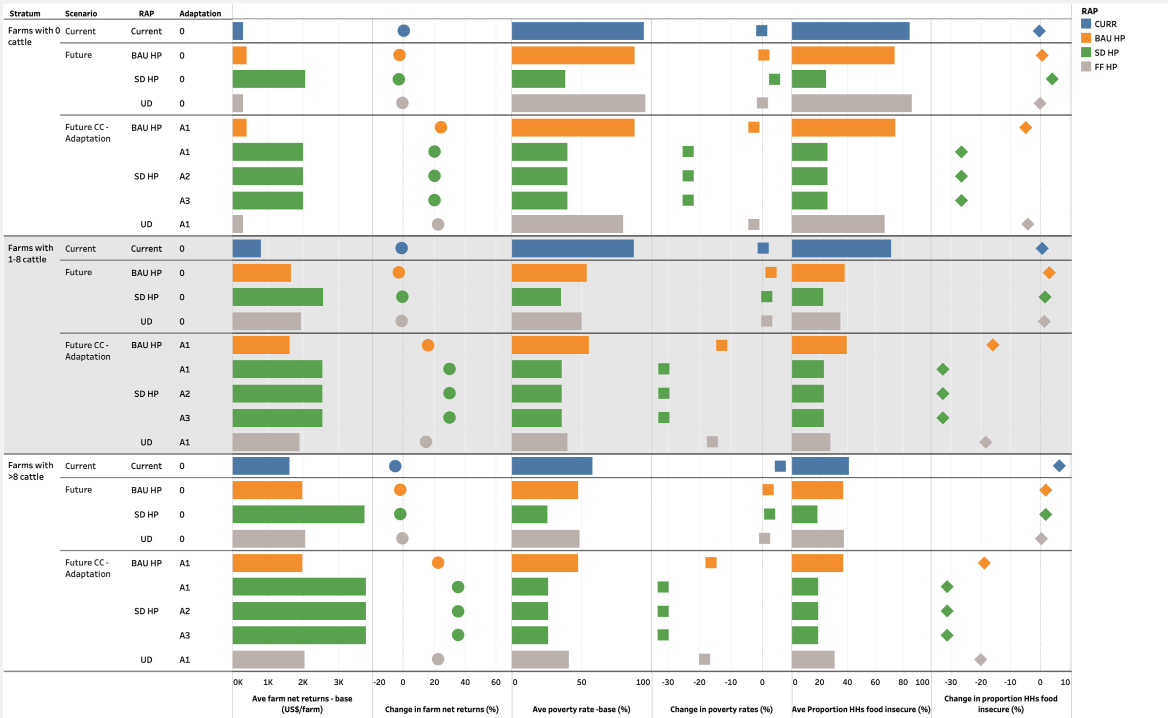

Figure A1. Nkayi, Zimbabwe. Farm net returns poverty and food insecurity under current and future conditions, climate change and adaptation.

Figure A2. Navrongo, Ghana. Farm net returns poverty and food insecurity under current and future conditions, climate change and adaptation.

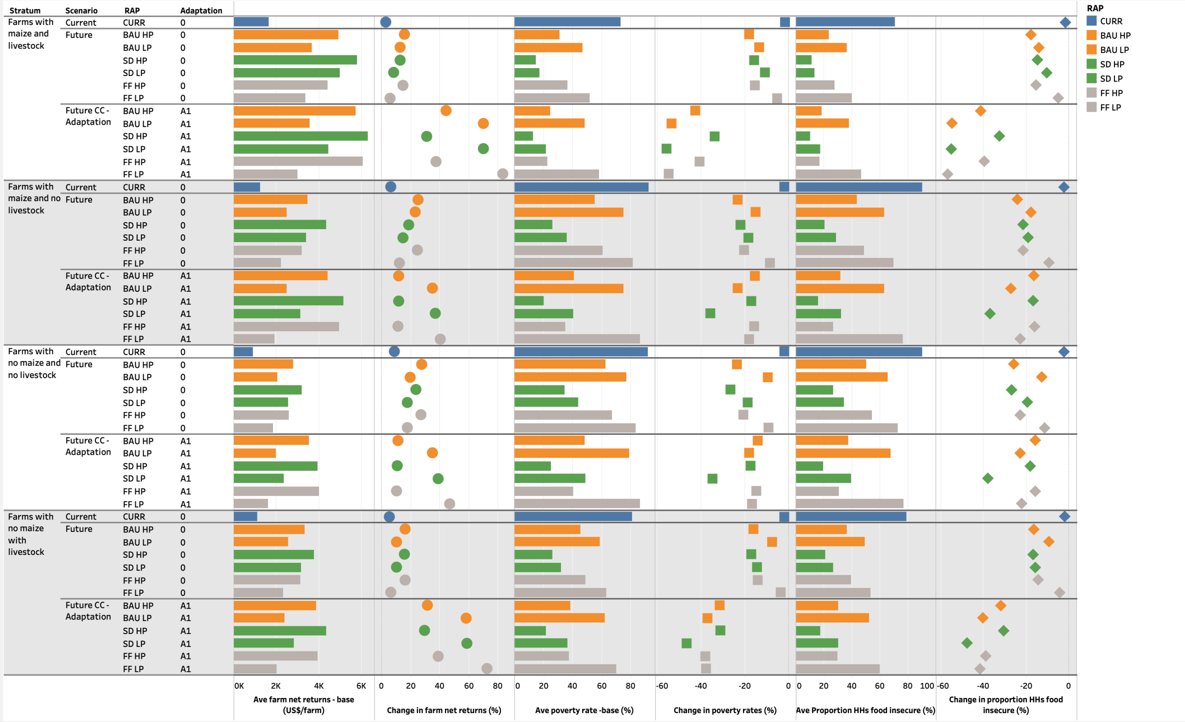

Figure A3. Nioro, Senegal Farm net returns poverty and food insecurity under current and future conditions, climate change and adaptation.

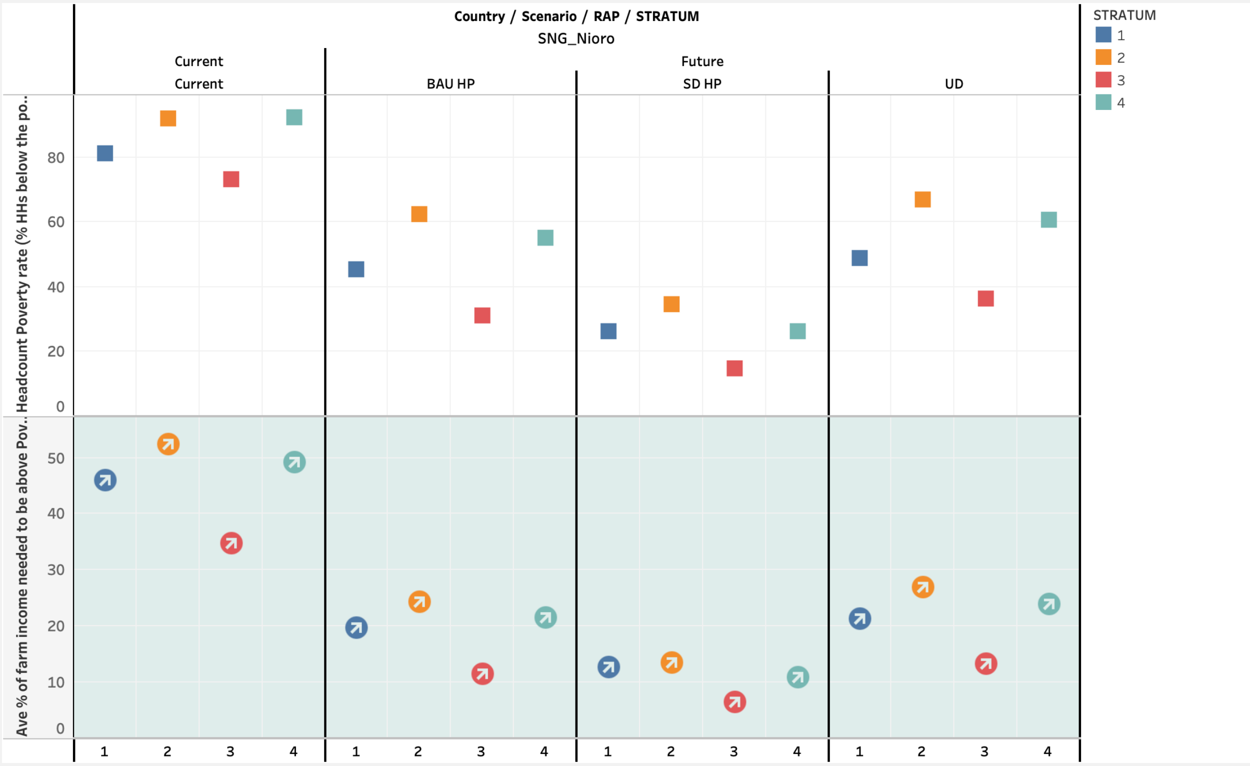

Figure A4. Nioro, Senegal. Poverty headcount and poverty gap under current and future conditions

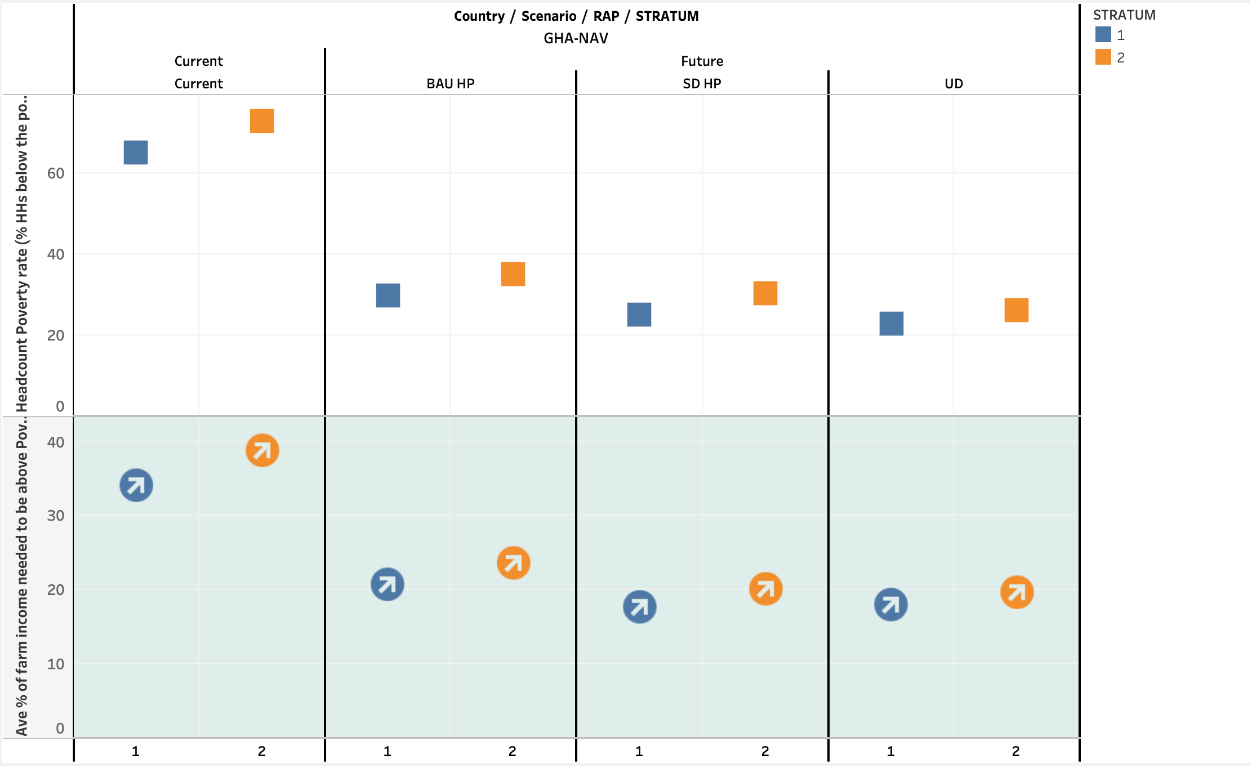

Figure A5. Navrongo, Ghana. Poverty headcount and poverty gap under current and future conditions

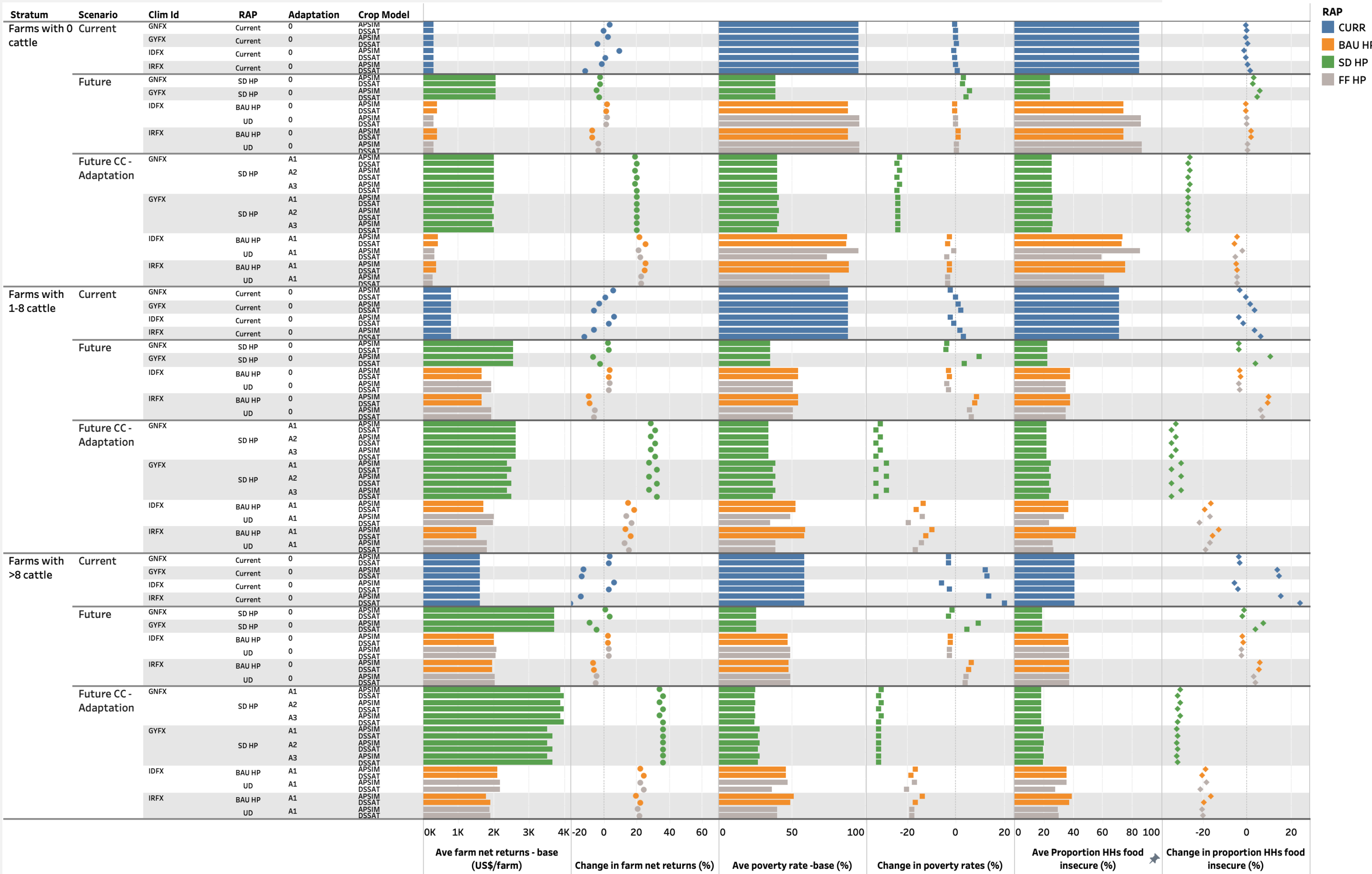

Figure A6. Nkayi, Zimbabwe. Results for key indicators from all simulation experiments: Current, future (RAPs) with and without climate change and adaptation

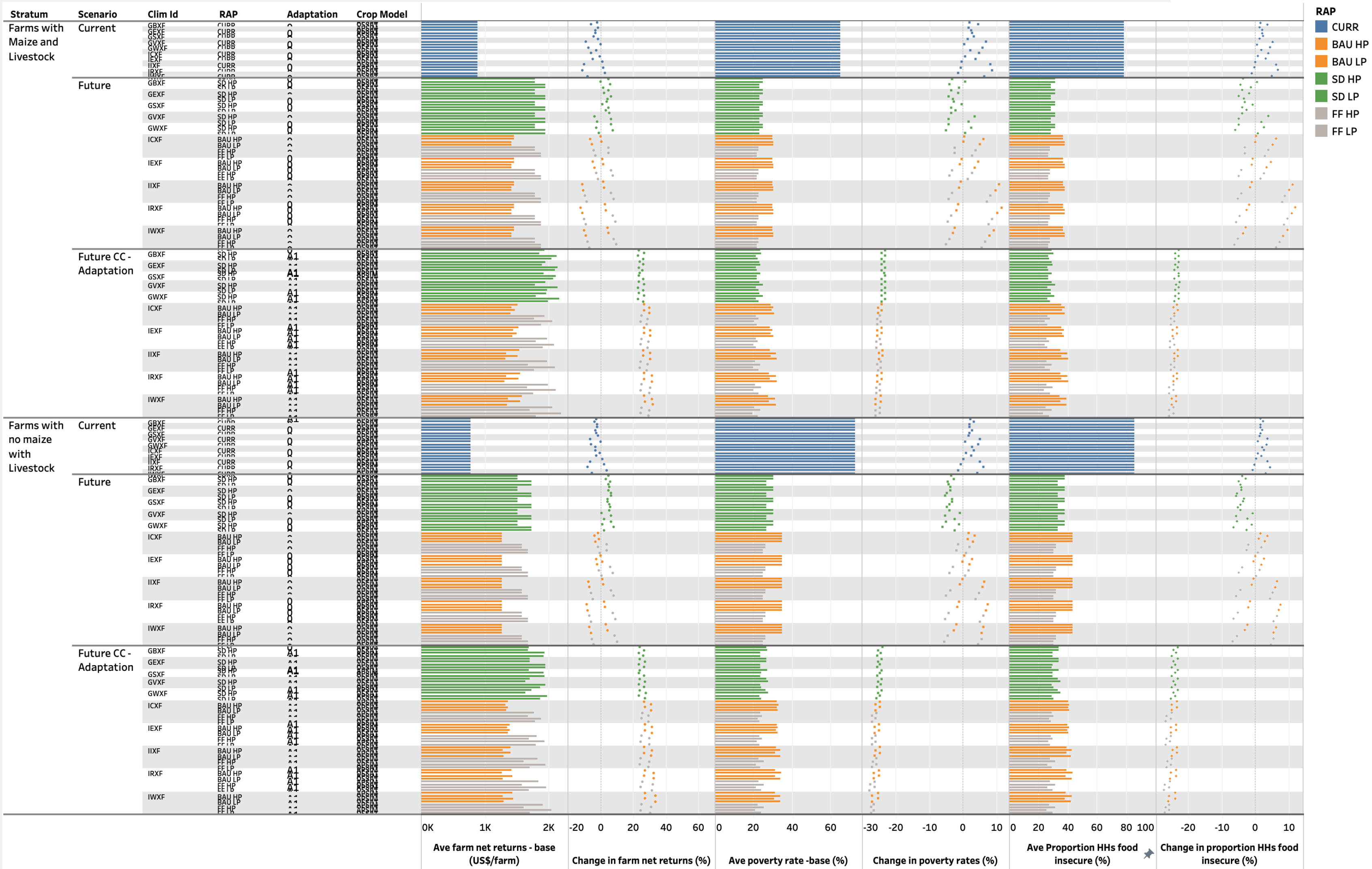

Figure A7. Navrongo, Ghana. Results for key indicators from all simulation experiments: Current, future (RAPs) with and without climate change and adaptation

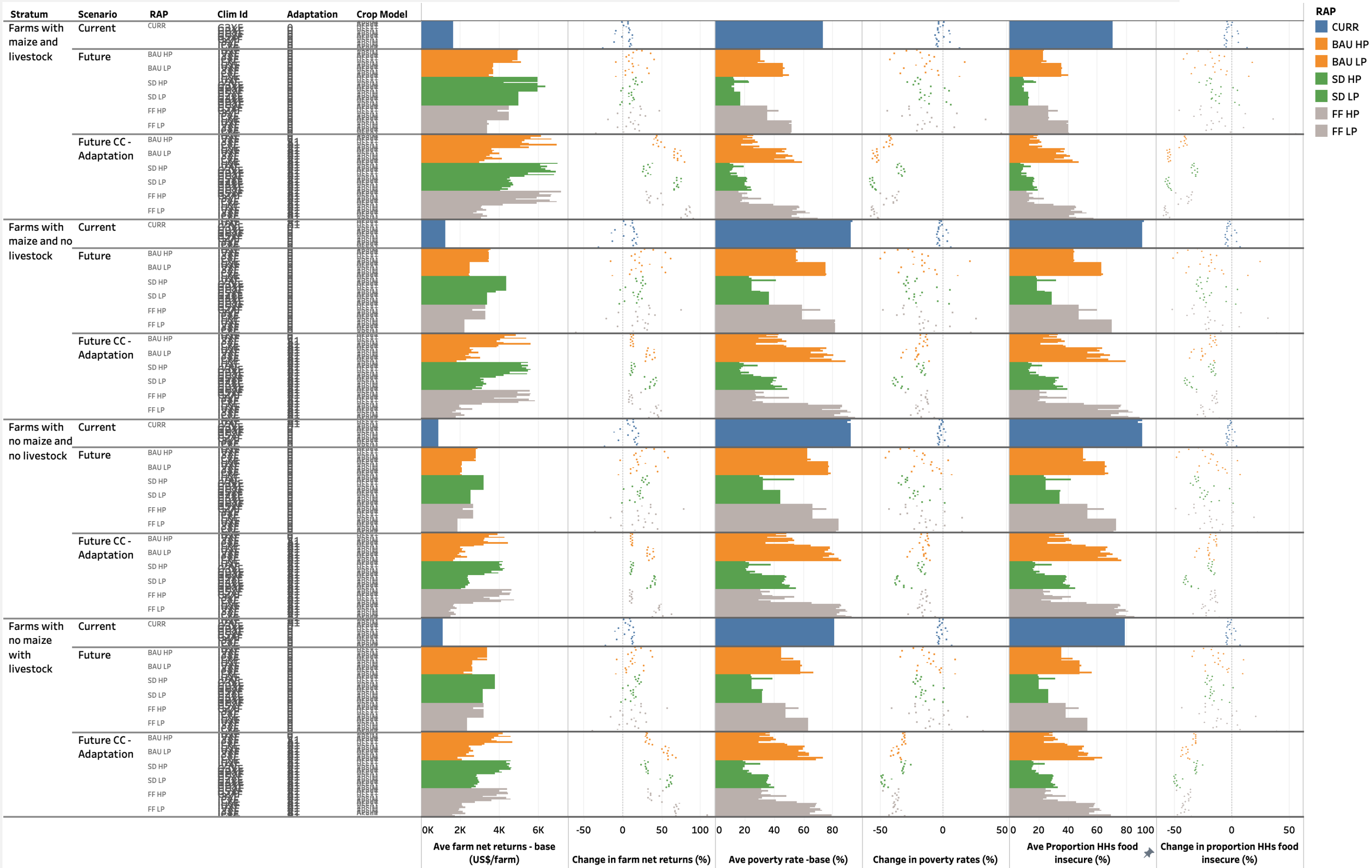

Figure A8. Nioro, Senegal. Results for key indicators from all simulation experiments: Current, future (RAPs) with and without climate change and adaptation

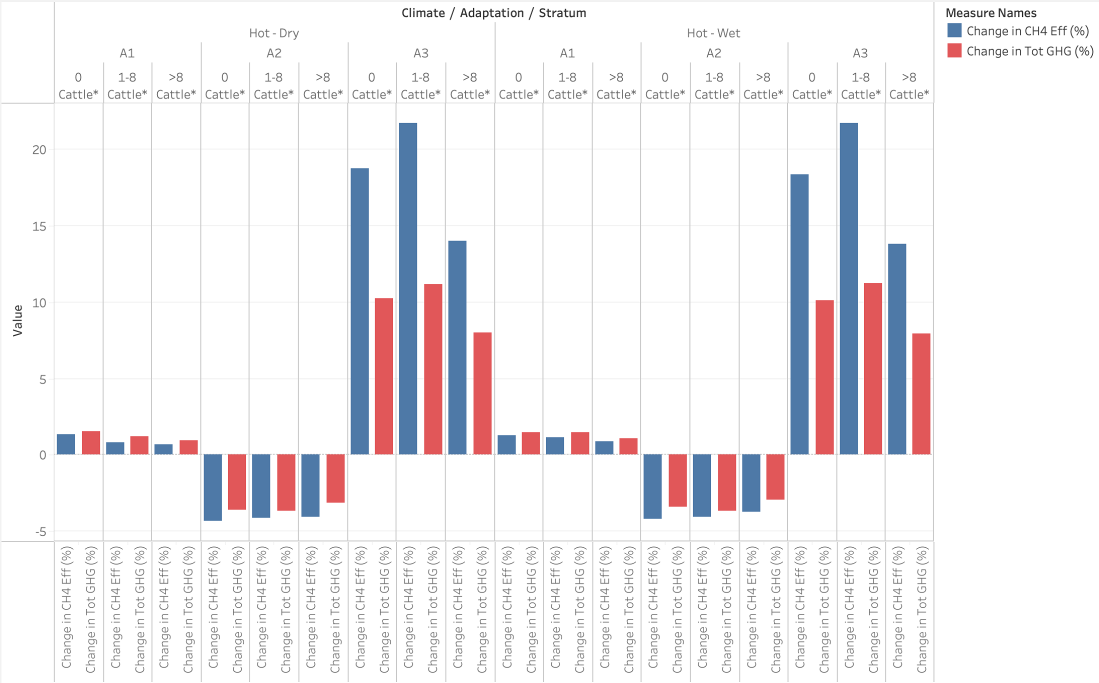

Figure A9. Nkayi, Zimbabwe. GHG emissions by strata and scenario. CH4 Eff= Methane from enteric fermentation; Tot GHG= Total GHG emissions.

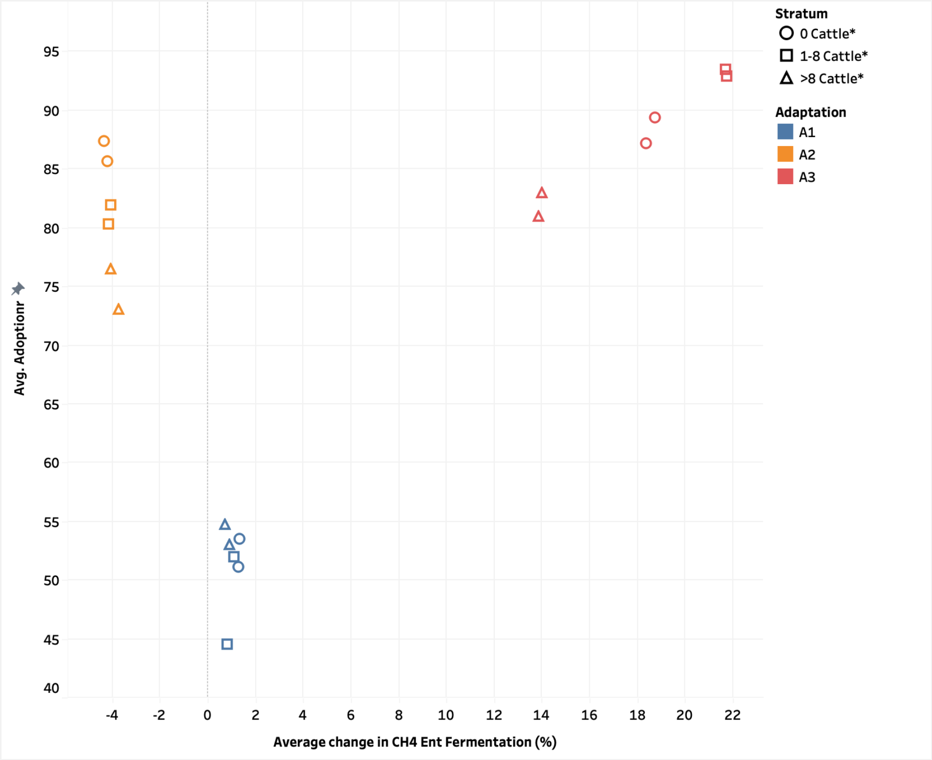

Figure A10. Nkayi, Zimbabwe. Adoption rates of adaptation packages and Methane emissions from enteric fermentation

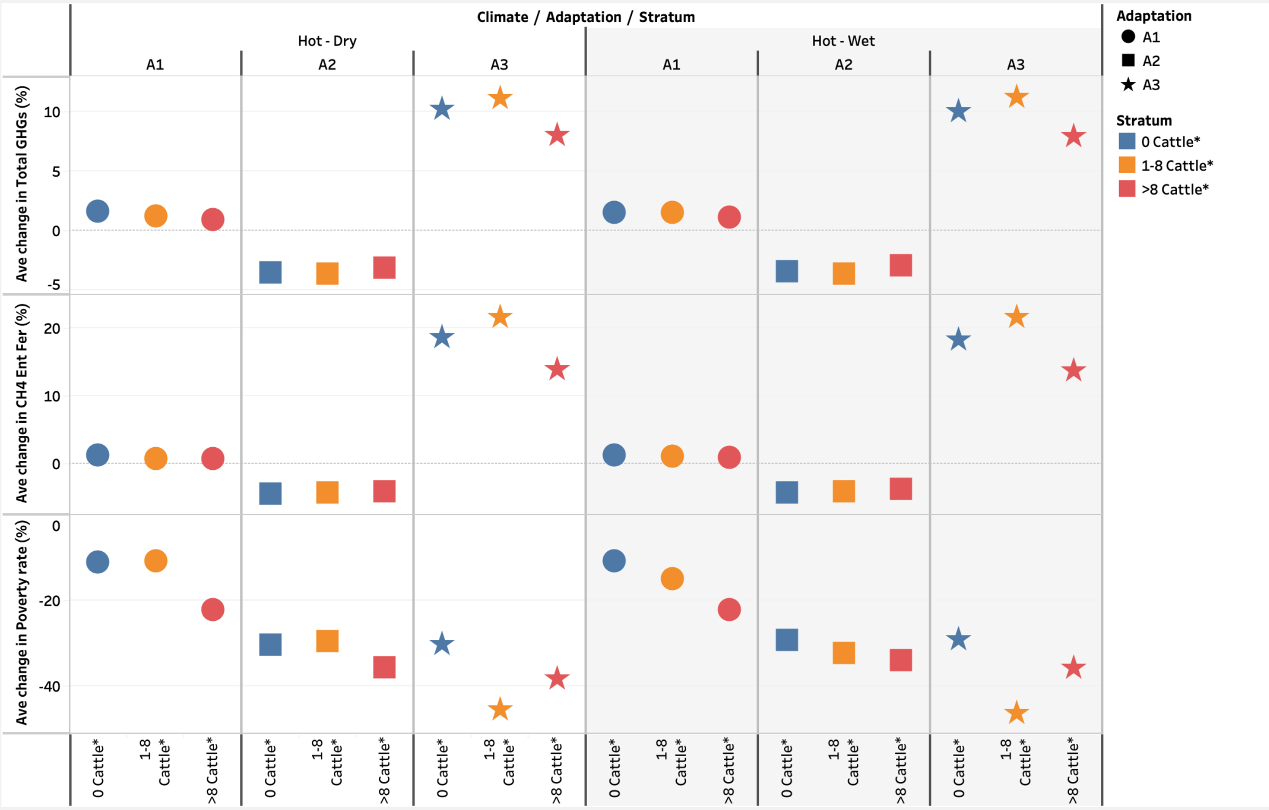

Figure A11. Nkayi, Zimbabwe. GHG emissions and poverty rate tradeoffs by strata for the different adaptation packages under the sustainable development RAP.

A Framework for Integrated National and Regional Assessments of Agricultural System Adaptation to Climate Change

John Antle, Roberto Valdivia, Sherwin Gabriel, Gerrit Hogenboom, Malgosia Madajewicz, Cheryl Porter, Cynthia Rosenzweig, Alex Ruane and Timothy Sulser

November 2021

This document describes the design and main elements envisaged for national model-based assessments of national adaptation plans (National Integrated Assessment, or NIA), implemented together with regional (sub-national) assessments of agricultural system risks, vulnerabilities and adaptations utilizing AgMIP Regional Integrated Assessment (RIA) methods. We describe the combined national and regional assessment as Integrated National and Regional Assessment (INaRA).

The first section provides an overview of the INaRA goals and approach. We then address INaRA design, including the linkage between model-based analysis and a country's National Adaptation Planning and related climate policy and other policy design and implementation. The remainder of this document provides additional details on the components of national assessments and the linkage to regional (sub-national) assessments of agricultural systems that use AgMIP's RIA methods.

Acronyms used in this report:

AgMIP	Agricultural Model Inter-comparison and Improvement Project
CMIP6	Coupled Model Intercomparison Project Phase 6
IFPRI	International Food Policy Research Institute
INaRA	Integrated National and Regional Assessment
NAP	National Adaptation Plan
NIA	National Integrated Assessment
NRDI	National-Regional Data Interface
RAP	Representative Agricultural Pathway
RCP	Representative Concentration Pathway
RIA	Regional (Sub-National) Integrated Assessment
SSP	Shared Socio-economic Pathway
UNFCCC	United Nations Framework Convention on Climate Change

INaRA Goals and Approach

The principal goals of INaRA are to:

- Analyze the country's agricultural sector performance under current and alternative strategies to implement its national adaptation plan (NAP), using stakeholder-defined performance indicators and national data and integrated assessment models;

- Complement and support regional integrated assessment (RIA) of agricultural system risks and adaptation at the regional (sub-national) level by regional teams of stakeholders and scientists.

A National Adaptation Plan (NAP) is a part of the ongoing process developed by the UNFCCC to identify medium- and long-term adaptation needs, and develop and implement strategies and programs to address those needs. For example, a NAP could establish the amount of funding earmarked for agricultural research on climate adaptation, and alternative strategies for implementation could establish priorities for particular regions and production systems in the country.

To achieve these two goals, INaRA begins with the identification of a set of scenarios defined over a stakeholder-defined planning horizon. Each of these scenarios is comprised of two main components: a strategy for national adaptation plan implementation; and a future pathway comprised of projected future climate conditions (associated with Representative Concentration Pathways, or RCPs) and socio-economic conditions (represented by global Shared Socio-economic Pathways, SSPs, and national Representative Agricultural Pathways, RAPs).

INaRA uses quantitative modeling to evaluate the performance of the country's agricultural sector and main agricultural systems for each scenario using stakeholder-defined performance indicators for each scenario (Figure 1). These indicators can be measures of agricultural productivity, prices, food consumption, food stability and other environmental and social indicators discussed in this report.

Using this approach, model simulations allow national stakeholders to evaluate alternative adaptation strategies, compare the range of plausible outcomes achievable with alternative adaptation strategies. The modeling methods also provide stakeholders with a way to evalkuate the uncertainty associated future climate and socio-economic pathways, as well as uncertainties associated with the models used

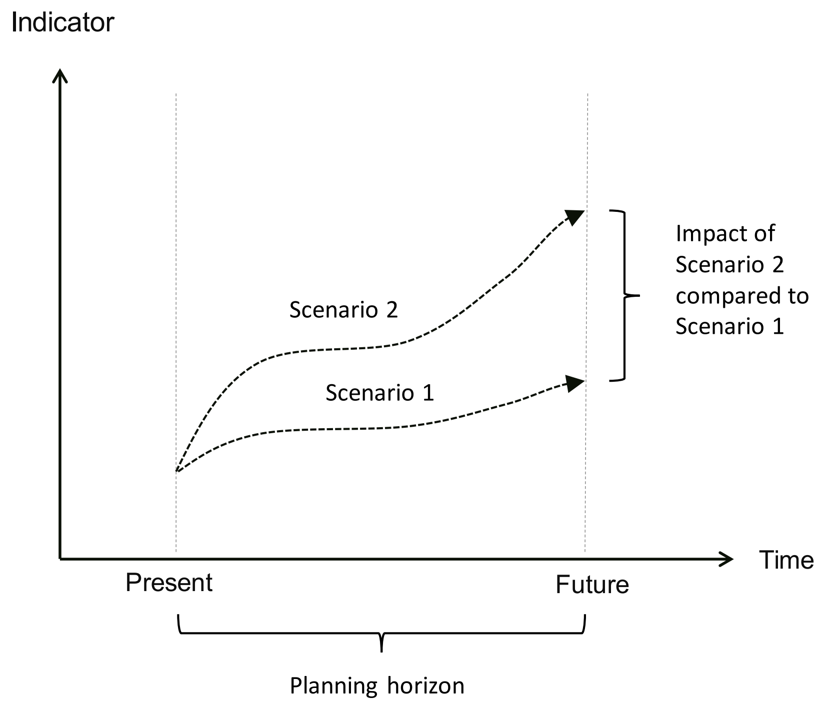

Figure 1. INaRA scenario design to assess alternative adaptation strategies. Each scenario is composed of an adaptation strategy and projected future climate projections (SSP-RCPs) and socio-economic pathways (RAPs). For example, Scenario 1 could be a "baseline" or "business as usual" scenario without adaptation and Scenario 2 could be a scenario with a specified National Adaptation Plan and a set of system-level adaptations.

INaRA Modeling: Design and Implementation

INaRA modeling is designed to project the future value of aggregate economic indicators (e.g., aggregate commodity productivity, production, consumption and prices), environmental indicators (e.g., greenhouse gas emissions, water, and air quality, aggregate fertilizer and chemical use), and social indicators (e.g., national per capita income and poverty rates, per capita food consumption and food security). The differences in the data and models at these scales create major challenges to INaRA implementation. For example, national analysis typically operates on an annual time step. In contrast, regional integrated assessments (RIAs) may operate on seasonal time steps suitable to farm systems and households and corresponding indicators such as farm income, crop production and yields, regional poverty, household food security. These time steps typically do not begin or end with the annual calendar. The entire agricultural sector of a country is comprised of many components from farm to national scales that are jointly and dynamically determined in space and time. However, due to the data and analytical challenges, it is not currently possible to simulate these large, complex systems at both regional and national scales as one large model.

The solution proposed here is to develop a process that involves both formal modeling at national and regional scales, as well as informal, expert-judgment processes to make linkages and ensure logical consistency between national and regional modeling. A spreadsheet tool, the "National-Regional Data Interface" (NRDI), provides a common set of identifiers and other information that enables coordination between scales (Figure 2).

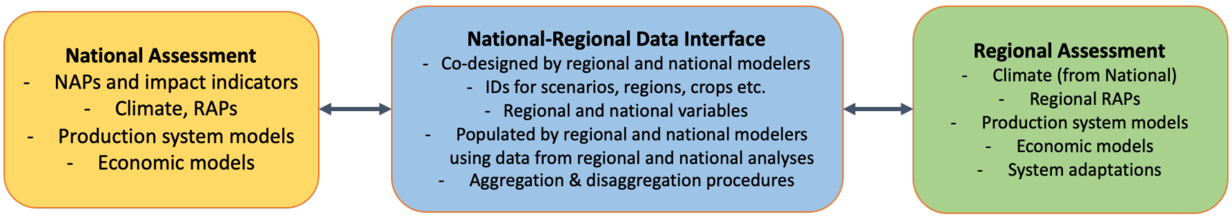

Figure 2. Linkage of national and regional (sub-national) modeling through the National-Regional Data Interface (NRDI)

INaRA aims to support a country's ongoing NAP process as well as related policy decision making. Critical elements of INaRA are therefore coordination with national institutions leading the NAP and committing resources to support the INaRA activities. Given the available resources, national and regional modeling teams need to be established and participate in the design of INaRA in collaboration with the NAP team and other institutions involved in related policy decision making.

The first step in INaRA is to make decisions about key components jointly with national stakeholders:

- national impact indicators to be included (quantitative and qualitative)
- national modeling team components and membership (climate, production systems, economics, environmental, and social component)
- regions & systems to be included, and members of regional teams to implement RIAs
- a work plan for national assessment and coordination with regional teams.

The national assessment is designed and implemented in coordination with a set of RIAs for each major region and agricultural system in the country. RIAs provide region- and system-specific analysis to support the national-level policy design and implementation. A key feature of an RIA is the regional and agricultural system-level specificity needed to design and evaluate farm-level adaptations effectively. The AgMIP *Guide for Regional Integrated Assessments: Handbook of Methods and Procedures, Version 7.0.* http://agmip.org) describes methods for the regional assessments. In many cases, the RIA methods will need to be adapted to fit the data availability, resource constraints and priorities of a specific country's INaRA.

INaRA implementation will involve a set of iterative steps to coordinate national and regional analyses. The fact that, in reality, national and regional outcomes are jointly determined in a complex, dynamic process creates a methodological "chicken-and-egg" problem. For example, national analysis requires estimates of regional system productivity; however, regional productivity depends on nationally or internationally determined prices. The national and regional teams will need to establish a set of initial assumptions to populate the NRDI, and then establish a schedule to coordinate national and regional analyses and iteratively update the NRDI.

INaRA Components and Linkages to Global and Regional Modeling

Figure 3 illustrates the main components and linkages in INaRA. The next section discusses indicators that can be used to assess performance at the national level. The subsequent sections provide anticipated protocols for each of the national modeling components.

National Indicators

A variety of economic, environmental and social indicators can be used, depending on data availability and the available models. Here we group indicators according to the three broad areas of sustainable development – economic, environmental and social. There are a number of systems of normative goals and indicators that are now being used. For example, progress towards the seventeen UN Sustainable Development Goals is measured with multiple indicators for each goal, and many of the SDGs are directly related to agriculture. The CGIAR has identified five specific impact areas: nutrition and food security; poverty reduction, livelihoods and jobs; gender equality, youth and social inclusion; climate adaptation and greenhouse gas reduction; environmental health and biodiversity.

An important limitation of model-based integrated assessment is the "bias" towards quantifiable indicators, with the consequence of often ignoring some environmental or social impacts that are difficult to quantify with available models. For example, Antle and Valdivia (2020) discuss the models that are available to quantify indicators related to the CGIAR's five impact areas, as well as the relevant impacts that are not currently quantifiable with models. To address this limitation, they recommend a stakeholder-based process that first identifies relevant outcomes and impacts in each of the three dimensions of sustainability, and then addresses how relevant indicators – both quantitative and qualitative – can be incorporated into the analysis. We envisage a similar approach for the identification of national and regional integrated assessment indicators. A process similar to the development of Representative Agricultural Pathways (RAPs) is appropriate for this purpose.

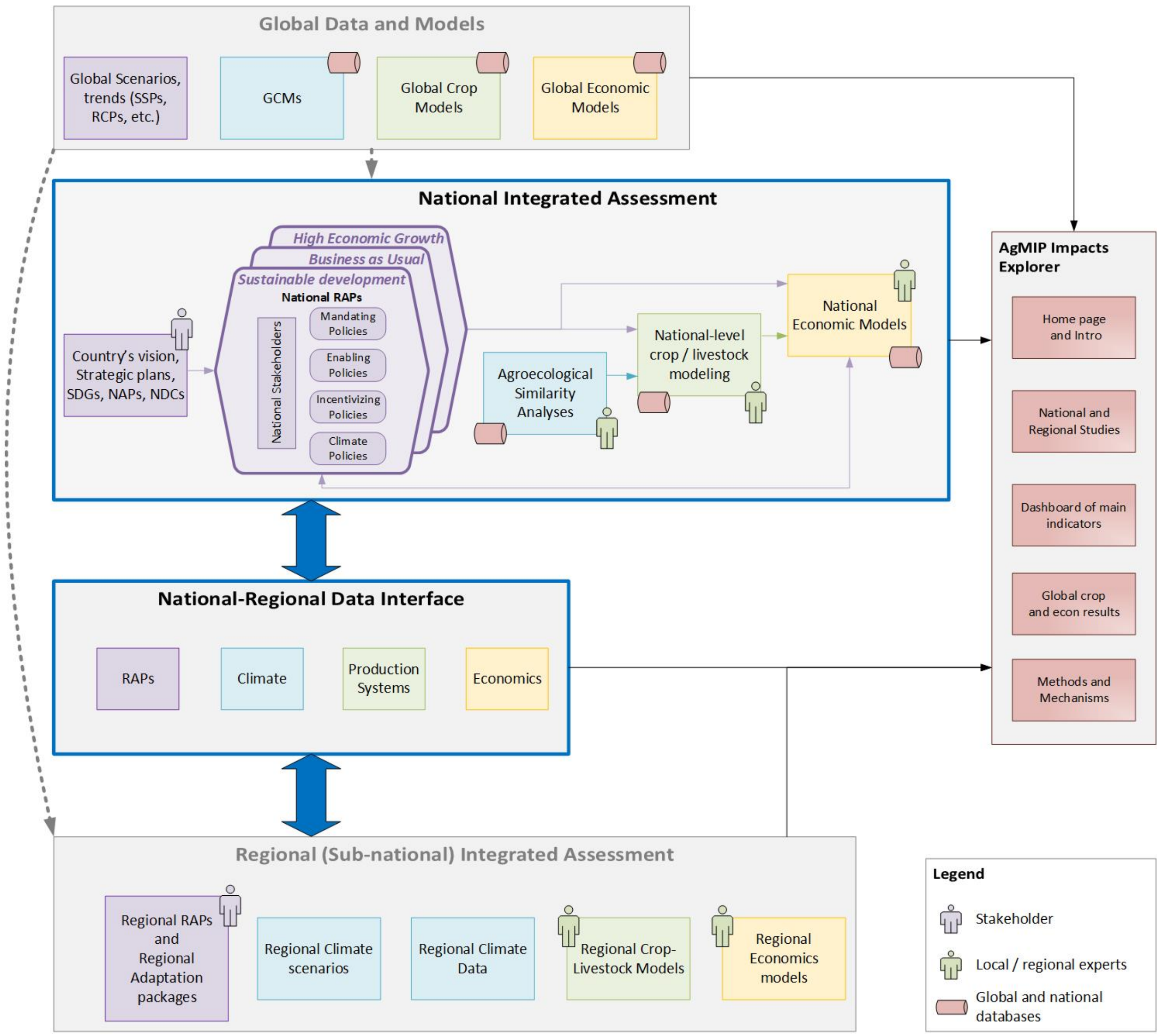

Figure 3. INaRA Components and Linkages.

An important aspect of the RIA method is to quantify vulnerability of farm households to climate impacts and the effects of adapting farm household systems to climate change. In addition to income vulnerability, food security indicators and indicators related to assets such as livestock can be used. This is an area where national models are very limited in their capability to represent impact, thus alternative methods should be explored. For example, review and synthesis of existing regional vulnerability studies, together with RIA vulnerability assessment, could be used to identify vulnerable regions, systems and populations. This information could be combined with national modeling to translate and disaggregate national outcomes into implications for vulnerable regions and groups.

Economic Indicators:

- Commodity productivity (i.e., crop yields)
- Commodity area and production
- Local commodity consumption
- Agricultural commodity prices
- Agricultural commodity trade (imports, exports)

Environmental Indicators

- Land area cultivated by conventional or conservation tillage
- Soil erosion
- Agricultural chemical use: organic and inorganic fertilizers, pesticides
- Energy use
- Irrigation and water use
- Net greenhouse gas emissions (carbon dioxide, nitrous oxide, methane)

Social Indicators

- Income distribution (poverty rates, urban and rural)
- Food security (various objective and subjective indicators; national, urban, rural)
- Gender equity (education, labor participation, asset ownership, income)
- Health (life expectancy, urban and rural, by gender and age)

Toward Protocols for INaRA Components

Climate

Climate information for INaRA activities will be drawn from observational datasets and climate models with the goal of providing daily climate series that may be used to drive production models (crops and livestock). Climate analysis will follow a common set of protocols to ensure that each regional and national element may be connected with the others under illustrative and coherent future storylines. Configuration of production models will prioritize local observations and national meteorological networks, with coarser global products available to fill in gaps. Projections will be rooted in the latest CMIP6 climate projections across low (SSP1-2.6), moderate (SSP2-4.5) and high emissions (SSP3-7.0) scenarios, with a subset of models selected to represent the global distribution of equilibrium climate sensitivities.

Practicality limits evaluation of all combinations of climate models, SSP-RCPs, RAPs, crop models and adaptation packages, and thus INaRA activities will develop an ensemble of bias-adjusted scenarios for analysis. The primary subset of climate scenarios will be selected to highlight particular storylines of regional change, including moderate and high local warming rates, shifts toward wetter or drier conditions, and shifts in locally-important climate features such as rainy season onset dates (building from Ruane and

McDermid, 2017). The resulting model subset will also be related back to the full CMIP6 set of models in order to understand the likelihood of each storyline in the broader CMIP6 ensemble.

Historical climate and future climate scenarios will cover each country from 1980-2100 with 0.5˚ x 0.5˚ resolution and will be bias-adjusted to better represent observed average and extreme conditions (e.g., from NASA NEX). The scenario set will also be further compared against finer resolution historical observations and dynamically-downscaled climate projections (e.g., from the COordinated Regional Downscaling Experiment, CORDEX) to identify residual differences in local features and regions where local topography, land cover or coastlines modify the rates of climate change. These comparisons will further contextualize results and provide additional detail about regional patterns of impact.

Representative Agricultural Pathways: Global, National and Sub-National

The process of developing RAPs across scales builds on the RAPs development protocols used in AgMIP's Regional Integrated Assessments of climate change and adaptation (Antle et al., 2015; Valdivia et al., 2021). The goal is to develop national-level RAPs that describe plausible futures aligned with the countries' visions of sustainable development and climate change policies. Regional (sub-national) RAPs incorporate policy and technological interventions set at national level and provide with storylines and quantifiable parameters to be used as inputs to crop-livestock and economic models. Additional RAPs representing different plausible futures can be developed to assess impacts of climate change on farming systems under different future conditions. The key to this process is ensuring the consistency across the scales.

Scales. The RAPs development approach is a nested approach that links drivers and outcomes across scales:

Global: Higher level pathways are used to define external drivers that may influence some of the National -and sub national- drivers. In AgMIP's scenario development Shared Socio-economic Pathways (SSPs) are used to describe the future global socio-economic conditions, including price and productivity projections

National: At this level, national RAPs include policies and agricultural planning that focus on the entire agricultural sector and cover the whole country. Drivers at national level might be influenced by external factors, like those in the SSPs or other aspects like international trade, international agreements, and commitments. National drivers in turn, influence the Sub-National drivers.

Sub-National: At Sub-National level, we can define RAPs at two sub-levels. In cases where geographical division is important for the implementation of the national policies (e.g., State, Province, etc), then RAPs can be developed for these levels. The regional RAPs contain most of the State/Province level narratives, but are focused to the specific farming system to be analyzed (e.g., Crop-livestock system in Nkayi, Zimbabwe). The quantification of key drivers of these RAPs are used to parameterize crop, livestock and regional and national economics models.

Linking Regional RAPs to National RAPs. Development of a Regional RAP follow these overall steps:

1. The process starts by characterizing the current state of the farming system, including the current policy conditions.
2. Using narratives of future global socio-economic scenarios (SSPs), information about current and proposed national policies (in some cases projected into the future) and with input from stakeholders and the team of scientists and experts, a description of "future states" of the agricultural farming system are created (overall RAP narratives).
3. With the definition of the future scenarios, an iterative process is carried out to identify the key drivers of change (policy/institutional, economic, technology and bio-physical) that would support the RAP narrative (i.e., the future conditions of the agricultural system).
4. The regional RAP is finalized by defining qualitative and quantitative changes for key drivers. The process starts over to develop additional regional RAPs.

In the AgMIP-CLARE project, regional and national RAPs were developed following the process described in Figure 4. Linkage of national-level RAPs to regional RAPs follows these steps:

1. Characterize the current state of the agricultural sector in the country. Use of available information to define the structure of the government, organizations and identify key stakeholders (those who can be part of the process during the project, and the high-level stakeholders to whom the results will be presented).
2. Identify and describe the long-term vision of the country using Sustainable Development plans, Strategic Vision, National Adaption Plans, etc. Focus on the agricultural sector, but also be inclusive of policies and plans from other sectors that may have an effect on the agricultural sector (e.g. energy, health, education, etc).
    - The strategic vision or sustainable development plans usually have key pillars around which policies and interventions are built to achieve goals regarding environmental protection, achieve economic efficiency, agricultural sustainable development, energy production, social equity, food security, etc. In many cases a set of indicators are associated with these plans.
    - The goal is to develop contrasting RAPs that highlight particular decision contexts, thus, after finalizing the RAPs that represent the future state under the strategic visions or country's sustainable development plans, a similar iterative process to create additional RAPs is started.

3. Using the above information, and the defined global SSPs, the team, invited experts and stakeholders define the plausible future states of the agricultural sector, or the 'overall RAP narratives'.
4. The next step is an iterative process that starts with identifying the key drivers of change (use the strategic vision, sustainable development plans, etc to determine these drivers). National and agricultural policies define the policy/institutional and socio-economic conditions of the National RAPs. The different types of policies help to contextualize RAPs, define the key variables that may have a direct or indirect effect on the sub-national level drivers. Examples of drivers and specific variables are shown in Table 1.
    - Once identified the key drivers, a process similar to the regional RAPs is followed: Using the DevRAP matrix, for each driver, a direction and magnitude of change is proposed. Storylines to justify these changes are elaborated and levels of agreement are assessed.
    - As in the regional RAPs, variables are assigned to team members, experts and stakeholders to research about the plausible trends following the overall narrative. All documents, studies, papers, etc. used need to be documented and stored on a shared Google Drive folder.
    - The team will revise the storylines as they are crafted to make sure there is internal consistency across the drivers.
    - The output of the iterative process is a full draft of National RAPs.
    - The next step is to revise the regional RAPs to make sure there is consistency across scales.
    - The team will meet and review and discuss the full Regional and National RAPs.
5. New RAPs can then be developed by following the same iterative process with the main goal of identifying those drivers that would lead to an alternative future state (e.g. a less sustainable development oriented RAP).
6. The quantification of the revised regional RAPs will be input to the TOA-MD model and complement the data needed to implement the RIA. Outputs from this process will be included in the NIA

Mapping National Policies to RAPs. In order to help with the process of identifying the key drivers from National policies and link them to the RAP process, we use a Policy Matrix template created in Excel. This matrix lists all drivers and specific variables that are key to describe the national and agricultural policies in the context of the country's strategic vision, sustainable development plans and climate change plans (NAPs, NDCs, etc). The matrix also allows to identify how they may influence regional RAPs and how they are influenced by global scenarios (SSPs).

The policy matrix helps to categorize the type of policies as: 1. Enabling; 2. Incentivizing; 3. Mandatory; 4. climate policies; and 5. guidelines or programs implemented or planned by the government.

The team uses this matrix to evaluate importance of each policy and how these can be incorporated and quantified in the different RAPs. In addition, climate policies are used to develop assumptions about the implementation of future climate policies (Shared Policy Assumptions, SPA).

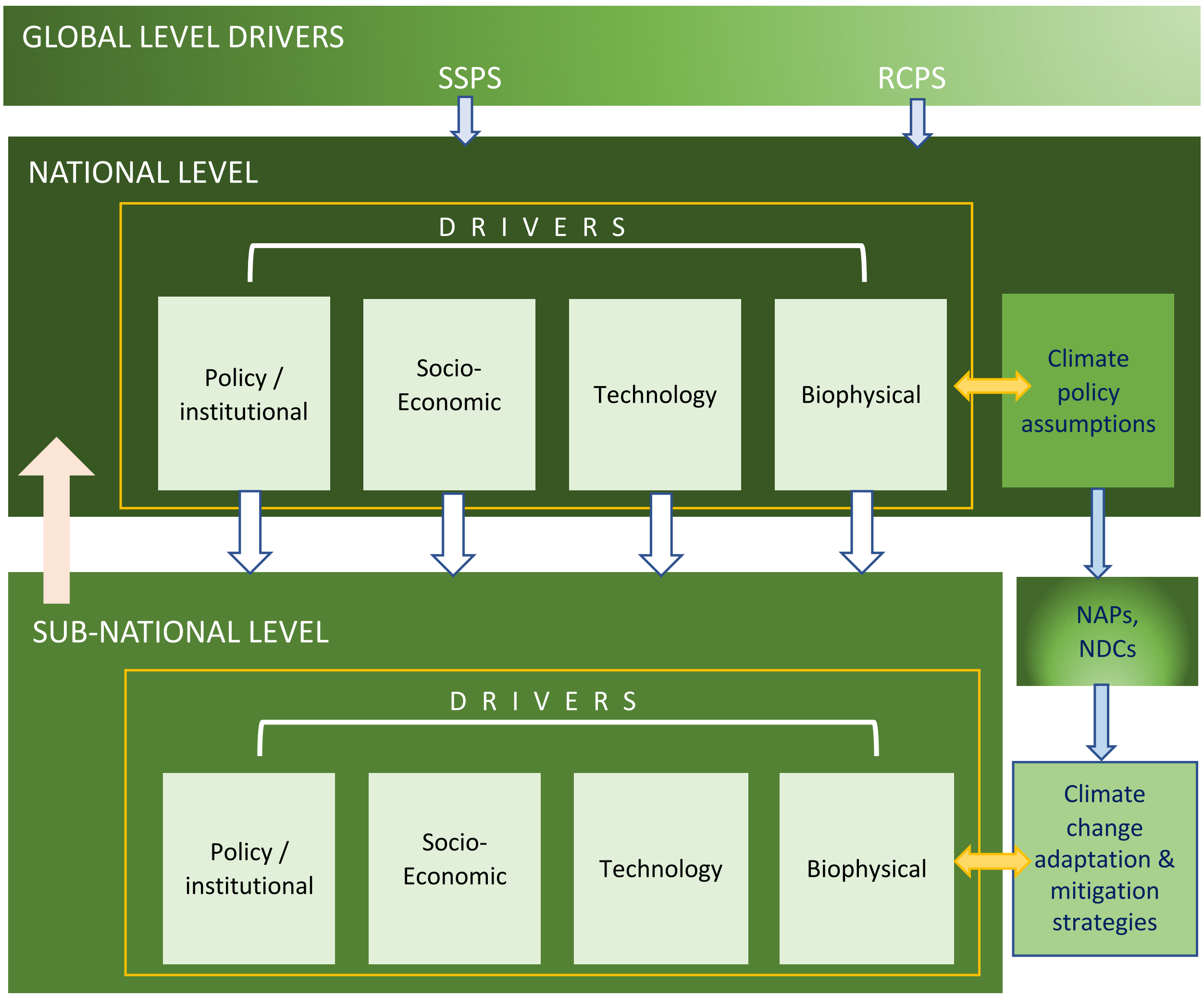

Figure 4. Linking RAPs across scales: Global-National-Sub-National

Driver	Variables
Regional Development	Context: Regional; West Africa (ECOWAS)
Economic growth	GDP, Agricultural GDP share
Population	Population growth, rural to urban migration
Literacy	Education investment, programs
Healthcare	Investment on healthcare, programs
Land Use	Expansion/contraction, change to new crops (as policy, incentives, land protection, etc)
Energy	Fossil fuel use, policies
Agricultural policies	Subsidies, taxes, quotas, policies on specific commodities, PES
Food production policies	GMOs, organic, etc
Environmental policy	Conservation policies, etc
Climate change policies	NAPs, NDCs strategies
Trade policies	Tariffs, imports/exports
Technological change	R&D investment
Water	Water use and allocation regulations, bio-physical conditions
Biodiversity	Regulations on biodiversity, incentives, PES
Level of governance	National and Sub-National
Sub-national development	Rural development policies
Social policy	Education, equity, gender
Markets	Investment, infrastructure, price controls/ceiling

Table 1. Example of drivers and variables for nationall RAPs (PES = payment for ecosystem services, GMO = genetically modified organism)

Crop Production Models

Crop Simulation Models can be used to simulate the spatial distribution of crop yield and production across the national domain using GIS-based data layers for soil properties, weather, management, and cropping areas. The resolution of the data inputs may vary based on data availability, but typically a spatial grid size of 5 arc-minutes (about 11 km) is sufficient to characterize the spatial variability of crop yields. Average or typical values of modeling inputs are used for simulation of yields in each pixel or grid cell.

Inputs to gridded crop model simulations include:

- Weather data products as described above in the "Climate" section. These products are based on satellite data and are generally at a courser resolution than many other crop production inputs.
- Soil properties. Several digital soil properties products are available, with quality and spatial resolution dependent on location.
- Crop management data, including cultivar and crop selection, fertilizer application rates, and cropping calendars are available in digital, gridded formats. These data products also vary widely with location and crop. In all cases, the products should be supplemented with local knowledge of the cropping systems being modeled.
- Cropping area masks supply information about the location and intensity of cropped areas for different crop and management types.

Estimates of the spatial distribution of cropping area are combined with simulated yields to compute crop production in each pixel. Production values can then be aggregated to national and other administrative boundaries.

Calibration and evaluation of crop production is done at the country or Administrative Level 1, depending on availability of production statistics.

Yields from gridded national crop simulations can be compared to yields simulated for regional integrated assessments, although the results are not expected to be exact due to the different types of input data. Input data for RIA crop model simulations are measured at specific farms, whereas the national gridded simulations are based on large-scale average values of input data. However, regional trends for climate change and socio-economic scenarios are expected to be similar for both methodologies.

Many minor crops and livestock activities cannot be modeled with current models. In the RIAs, these gaps are filled with data from literature reviews and expert judgment. For national analysis, similar procedures will be required, and the results will be incorporated into the NRDI so that consistent values are used for both national and regional analyses.

Crop models can be used to predict many variables related to crop growth and development, environmental variables, GHG emissions, resource requirements. The variables of interest in RIA and NIAs are crop yield and production for the most important commodity crops in the country. Crop models can also be used to produce information on resource requirements for irrigation and fertilizer; environmental variables such as nitrogen leaching or soil organic matter depletion; and the shifting of crop timing due to climate change.

Crop yield and production data to be included in the IE includes:

1. National crop production variation maps (i.e., raster images, typically on approximately 11 km resolution),
2. Production difference maps for selected scenarios,
3. Tabulation of crop production by administrative level 1, and
4. Comparison of anticipated crop yield variation between scenarios using box and whisker diagrams

Livestock models also are required for both regional and national analysis. Some national models have explicit livestock components including meat and dairy production. Regional analyses also need to incorporate livestock. The complexity of livestock production systems poses significant challenges at both regional and national scales. This is an important area where collaboration among regional and national researchers will be required to populate the NIA so that consistent assumptions are used at both scales.

Environmental Models

A number of environmental models are available for use at the national level, depending on the capabilities of the modeling team and data availability. For example, the IFPRI IMPACT model includes a water model that simulates water availability for agriculture. Some agricultural system models include environmental components, such as soil carbon or nitrous oxide emissions. However, due to the site-specific character of most environmental processes and outcomes, environmental modeling may be best implemented at the regional (sub-national) scale.

Agroecological Similarity Analysis

Analysis of climate, soil, agricultural management, social, and remote sensing geoinformation provides further information about common agroecological conditions and challenges within the country. Regional maps show the extent of specific evaluated systems in order to identify the broader areas where specific adaptation packages are viable. Analysis also provides insights about regions that are already experiencing challenges that will be more widespread in the future, and points toward adaptations that are currently in practice to overcome those emerging risks.

National Economic Model

Most national economic models that are appropriate for use in INaRA simulate national-level agricultural commodity markets (demand and supply), and their linkage to international markets through trade. When being used for INaRA, they are used to simulate the effects of climate adaptations and related policies on national outcomes such as agricultural production, consumption, prices and trade.

Most agricultural models are referred to as "partial equilibrium," because they represent the determination of agricultural commodity prices, production and consumption, taking other drivers such as income as given by the other parts of the national economy. In contrast, general equilibrium models simulate the functioning all commodities, factors, and institutions within the economy, and in which adjustments to relative prices ensure that all markets clear, but do so at a higher level of aggregation and thus provide less detail on individual agricultural commodities. Partial and general equilibrium models have different strengths and weaknesses, but complement each other when analyzing long-run trends under climate change.

A nationally focused partial equilibrium model, such as IFPRI's IMPACT-SIMM model, presents a tractable, and practical tool for examining detailed country scenarios.

Linkages to global economic models: Data requirements for the national economic model can be extensive. Baseline data, such as world prices, population, income, supply and demand indicators, trade, irrigation, elasticities, and productivity growth, can reasonably be linked to larger, global models with consistent units, and commodity and geographic coverage. In this way, the national model can be initialized to the results of a global economic model, ahead of any policy-adjusted scenarios.

Linkages to national RAPs: Policy choices used in scenarios in the national (or regional) RAPs process can be different to baseline values, and meaningfully influence outcomes in the economic model. These include assumptions of economic and population growth, which can influence the level of household demand in scenarios. Also, policy choices such as tariffs and subsidies can exert pressure on consumer and producer prices. These should be incorporated into the economic model to ensure that results correctly capture the effects of those assumptions/policy actions. As far as possible, tariff and subsidy assumptions should be made at the commodity level, with guidance as to how the policy change is implemented over time.

The results from the national economic model can be passed back to the national RAPs to examine potential effects of different policy choices on variables such as domestic prices, production, planted areas, and yields, among others. These outputs can be used to inform a refined design of adaptation packages and contribute to the iterative process with the RIAs.

Linkages to crop simulation models: The national economic model can draw policy-adjusted crop yield or area results from crop simulation models, as scenario inputs. These would impact supply-side variables such as production. Data from crop simulation models, which are often done at a detailed spatial level, should harmonise with the geographic units available in the economic model.

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13.4.1 Agroclimatic Similarity Methods Technical Matter

Table A13.4.1: Layers factored into agroclimatic similarity analysis for Nkayi, Zimbabwe.

	Variable Layer Name	Units	Product Spatial Resolution	Product Temporal Resolution	Evaluation Period	Nkayi farms avg value	Similarity Range	Product Description
Biophysical Layers	**Mean NDVI***	NA	250 m	16-Day	2000-2020	--	--	[MOD13Q1]
	Min NDVI*	NA	250 m	16-Day	2019- 2020	--	--	MOD13Q1
	Max NDVI*	NA	250 m	16-Day	2019- 2020	--	--	MOD13Q1
	Mean EVI	NA	1km	16-Day	2000-2020	0.2661	0.2394 to 0.2927	MOD13A2
	Min EVI	NA	1km	16-Day	2000-2020	0.0935	0.0692 to 0.0622	MOD13A2
	Max EVI	NA	1km	16-Day	2000-2020	0.6252	0.5462 to 0.6008	MOD13A2
	DOY min EVI*	Julian Day	1km	16-Day	2000-2020	--		MOD13A2
	DOY max EVI*	Julian Day	1km	16-Day	2000-2020	70	65-75	MOD13A2
Land Layers	**Land Cover***	Classes	1km	10-year	2010-2019	--	--	MODIS
	Soil Moisture Profile	Root-zone fraction	10 Km	3-Day composites	2016-2020	0.25	0.225 to 0.275	NASA enhanced SMAP
	Subsurface Soil Moisture	mm	10 Km	3-Day composites	2016-2020	25.87	23.283 to 28.457	NASA enhanced SMAP
	Agro-Ecological Zone (AEZ)	NA	NA	1-year	2020	III & IV	III & IV	Zimbabwe National Geospatial and Space Agency
Current Climate Layers **	**# Extreme Heat Days (Tmax > 35 °C)**	Days	0.5°	Daily	1990-2020	5	4 to 6	ISIMIP3 Ensemble of 5 Bias-adjusted General Circulation Models (GCMs; Lange et al., 2019)
	Total Precipitation	mm	0.5°	Daily	1990-2020	636	572 to 700	ISIMIP3 Ensemble of 5 Bias-adjusted GCMs
	Mean Temperature	°C	0.5°	Daily	1990-2020	23.2	20 to 25	ISIMIP3 Ensemble of 5 Bias-adjusted GCMs
	# Rainy Days (P > 1 mm)	Days	0.5°	Daily	1990-2020	59	52 to 65	ISIMIP3 Ensemble of 5 Bias-adjusted GCMs
Future Climate Layers **	**# Extreme Heat Days (Tmax > 35 °C)**	Days	0.5°	Daily	2040-2070 (SSP585)	30.5714	27 to 34	ISIMIP3 Ensemble of 5 Bias-adjusted GCMs
	Total Precipitation	mm	0.5°	Daily	2040-2070 (SSP585)	672.8741	605 to 740	ISIMIP3 Ensemble of 5 Bias-adjusted GCMs
	Mean Temperature	°C	0.5°	Daily	2040-2070 (SSP585)	25.57	23 to 28	ISIMIP3 Ensemble of 5 Bias-adjusted GCMs
	# Rainy Days (P > 1 mm)	Days	0.5°	Daily	2040-2070 (SSP585)	57.92	52 to 64	ISIMIP3 Ensemble of 5 Bias-adjusted GCMs
Future Climate Change Layers **	**Change in # Extreme Heat Days (Tmax > 35 °C)**	Days	0.5°	30-year means	SSP585 2040-2070 vs. 1990-2020	25.5	23 to 28	ISIMIP3 Ensemble of 5 Bias-adjusted GCMs
	Change in Total Precipitation	% of baseline	0.5°	30-year means	SSP585 2040-2070 vs. 1990-2020	-0.6783	-0.61 to -0.75	ISIMIP3 Ensemble of 5 Bias-adjusted GCMs
	Change in Mean Temperature	°C	0.5°	30-year means	SSP585 2040-2070 vs. 1990-2020	2.38	2.28 to 2.45	ISIMIP3 Ensemble of 5 Bias-adjusted GCMs
	Change in # Rainy Days (P > 1 mm)	Days	0.5°	30-year means	SSP585 2040-2070 vs. 1990-2020	-1.215	-1.0 to -1.33	ISIMIP3 Ensemble of 5 Bias-adjusted GCMs
Socioeconomic Layers	**Population Density**	persons / km	1 Km	5-year	2000	20.98	18 to 22	[GPWv411 Population Density]
	Population Density	persons / km	1 Km	5-year	2020	26.146	23.5 to 28.75	[GPWv411 Population Density]
	Livestock Density- Cattle	# cattle / pixel	0.83°	1-year	2010	1527.128	1374 to 1680	[Gridded Livestock of the World]
	Livelihoods	NA	NA	1-year	2020	ZW09	ZW09, 16, 17, 21, 24	Zimbabwe National Geospatial and Space Agency (ZINGSA), 2020

* Layer not a focus of current analyses

** Calculated over the Maize growing season for each ½ degree pixel (from Müller et al., 2017, Geo. Mod. Dev. 10, 1403-1422, doi:10.5194/gmd-10-1403-2017.)

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