Climate Change, Natural Resources and Management of Production Risks

AgMIP The Agricultural Model Intercomparison and Improvement Project

IICA

Enhancing Agricultural Production and Food Security amid a Changing Climate: **A New Approach to Inform Decision-Making**

Key Messages:

As a risk multiplier, climate change enhances the urgency of transforming to a more inclusive, competitive and sustainable agricultural system.

Stakeholders (government authorities, technicians and producers) need better decision-making support tools based on robust science that allow them to make effective investments.

Cutting-edge tools and science-based information allow for a better understanding of the possible impact of different adaptation measures or investments in socio-economic, environmental and productive variables under a changing climate.

An approach that integrates climate, crop, livestock, and socio-economic tools and data at various scales, such as AgMIP's Regional Integrated Assessment, can help identify and prioritize both short and long term strategies for the agriculture sector across different geographic scales.

Regional Integrated Assessment provides critical insight to inform the design and evaluation of national policies aiming to meet sustainable development goals, adaptation objectives, and commitments to reduce GHG emissions.

What regions and production systems are more vulnerable to climate change? Who might benefit and who might lose along different developmental pathways? What interventions can provide sustainable benefits to farmers and other agriculture sector stakeholders? What incentives are needed to achieve broad adoption of sustainable agricultural approaches? What are the potential tradeoffs and timelines of different investments?

Balancing act. Decision makers in the agriculture sector face a tough task in guiding the development of the sector to enable it to sustainably increase productivity and thus feed a growing and developing population under a changing climate (Mbow et al, 2019). Agriculture is the lynchpin for success in achieving the 17 Sustainable Development Goals in the Americas and must make significant contributions to economic, social and environmental objectives to which the different countries aspire in the face of growing global and regional challenges. With a need to increase

production 60 percent by 2050 to meet the nutritional needs of 9+ billion people, appropriate planning and decisions must be made to enable transformation of production systems while reducing water and input use, maintaining soil health, decreasing greenhouse gas emissions, improving farmers' livelihoods and facilitating economic growth.

Climate change: a risk multiplier

Agricultural livelihoods, food, and nutrition security in the Americas are vul¬nerable to weather shocks and climate change (Figure 1). Food security challenges are widely distributed, affecting both urban and rural populations in wealthy and poor nations alike (Brown et al, 2015; Ruane and Rosenzweig, 2019). Climate change impacts on global food security are likely to be negative, but vary by region. The tropics and sub-tropics are projected to have the more negative impacts, while some areas in high latitudes may actually benefit from climate change. While there are several studies and projections at the global level, the uncertainty is greater at the country level and for the range of impacts across different types of agricultural systems. Impacts are highly dependent on geographical, bio-physical, and socio-economic conditions and the type of farming systems employed (Mbow, 2019). This multi-dimensional heterogeneity poses a great challenge for making decisions regarding the development of the sector.

Planning the response. Countries are in the process of developing National Adaptation Plans (NAPs) and adjusting their Nationally Determined Contributions (NDCs) to meet their national and international commitments to address both mitigation and adaptation[1]. Given the climate risks facing the sector, and

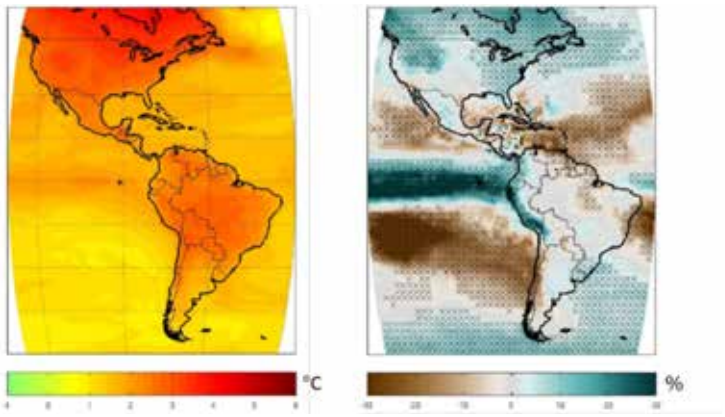


Fig 1 – Median projected changes across 21 NEX-GDDP downscaled climate models for RCP8.5 (high-emissions) mid-century (2040-2069) compared to 1980-2005 baseline for (a) annual temperature; and (b) annual precipitation. Hatch marks in (b) indicate areas where at least 70% of models agree on the direction of precipitation change (all regions have strong agreement on warming in (a)). Warming is stronger over land, with regional differences in warming rate and precipitation changes. Note that individual models show a wide range of potential wet and dry outcomes for many regions.

that almost a quarter of global emissions are attributed to agriculture and land use change, agriculture is a fundamental part of the solution (WRI, 2018, Mbow, et al, 2019). The strategies, programs and projects designed in response must adequately reflect the needs, priorities, and solvency of the sector. To ensure this, relevant and more accurate data and information on the likely impacts of climate change in the context of existing and proposed policies is required to 1) inform the development of effective adaptation and mitigation strategies and 2) understand the impacts of these

1. In compliance with the 2015 Paris Accord of the United Nations Framework Convention on Climate Change (https://bit.ly/2EVSoXT)

interventions on people, livelihoods, economies, and the environment.

The information challenge. Gathering supporting evidence to develop plans and climate-related policies has been challenging in most countries, especially given the inherent complexity of the agriculture sector, including multiple goals and actors at different scales. Countries have relied on the use of secondary information and the studies available in published literature (IICA, 2018). However, most national or regional studies of climate impacts are based on the analysis of individual crop or livestock species, or on aggregated economic outcomes such as crop revenue or net returns. These partial, aggregated measures of impact cannot provide an accurate representation of vulnerability or represent important aspects of management that are key to climate adaptation and mitigation.

Given the heterogeneity and diversity of actors in the agriculture sector, and the various social, economic and environmental contexts in which the agricultural activity takes place, the methods mentioned above and often used, are not optimal for assessing the impacts of climate change or adaptation and mitigation strategies. This is due to the:

- use of a representative farm approach or use of highly aggregated data, thus ignoring the diversity characterizing most of the agricultural production systems in the region. Most studies show average impacts on groups on groups of farm households within a region;

- inability to assess the distributional impacts that are key to understanding and identifying who gains and who loses from climate change, where and which policy or technology interventions are likely to benefit farmers, and which households are likely to be in greatest need of assistance under future conditions;

- use of only one or a few climate projections and scenarios, therefore missing the full range of uncertainty from climate data;

- available analyses are usually carried out under current socio-economic conditions (e.g., prices, incomes, technologies, policies) rather than under projected plausible future socio-economic conditions (potentially including structural shifts within the agriculture sector) that match the climate projections (e.g. 2050);

- difficulty in comparison of existing information, given that much of what is currently available is produced with specific objectives (within a project, thesis, etc.) and thus use a variety of different methods and tools.

An alternative is needed. Given the increasing risks that the agriculture sector faces, decision makers therefore require better tools and science-based information to inform policies and technological innovation. Agricultural models and linked tools can help identify and prioritize strategies for the agriculture sector, as well as shed light on the sectoral implications of strategies oriented beyond agriculture (Homann-Kee Tui et al., 2019). Novel assessment methods that integrate geo-physical, bio-physical and socio-economic information across temporal and spatial scales help to design and evaluate national policies aimed at meeting sustainable development, climate and food security goals.

A novel approach: The AgMIP Regional Integrated Assessments

The Agricultural Model Intercomparison and Improvement Project (AgMIP) has developed a response to this complex challenge - the Regional Integrated Assessment (RIA) of Climate Change Impact, Vulnerability and Adaptation of Agricultural Systems. 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.

What is RIA? This rigorous protocol-based approach helps understand 1) the sensitivity of current production systems to climate change, 2) the benefits of adaptations in current systems under the current climatic conditions, 3) the impacts of climate change on future production systems, and 4) which adaptation packages improve outcomes under current and future climatic conditions.

The RIA uses a participatory methodology, engaging 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 design of plausible future development scenarios. This approach ensures that the results are replicable and directly relevant for the stakeholders involved. It can test investments and interventions ex ante, thus helping to answer key questions including who gains and who loses from climate change in the current context, what regions or populations are most vulnerable, and what kinds of adaptation and mitigation packages benefit the most farmers and their livelihoods, while helping to build a more sustainable and prosperous national agricultural system.

AgMIP

Since 2010, this global consortium 1000+ experts at 60+ partnering institutions has been developing methods to study the current and future performance of agricultural systems. AgMIP utilizes a diversity of climate, crop, livestock, and economic data and models in combination with state-of-the-science information technology, storylines, and scenarios to conduct global and regional assessments of changing climate and other stresses on the agricultural sector with the goal of increasing the scientific rigor and quality of all agricultural models, and thus, improving the information that stakeholders can use to make decisions.

Key aspects that make this approach unique include (See Figure 2):

- A **transdisciplinary, systems-based focus** that reflects real complexities and can include multiple crops, livestock, aquaculture, off farm income sources, market interactions, and policy incentives in current and possible future systems;
- **Incorporation of a high degree of heterogeneity** in biophysical and economic conditions that are typical of most agricultural regions;

- **Quantification of not only average impacts, but also the distribution of impacts** in diverse populations;
- Ability to **test of different adaptations and technologies** and the potential impact of climate on both current and future production systems;
- Ability to **test and design policy interventions** aimed at increasing adoption of adaption and mitigation strategies to increase the likelihood of their success;
- Ability to **reflect both average climate changes** and interactions with **climate variability;**
- **Ability to differentiate between different types of farming systems** and producers;
- **Use of multiple climate, crop, livestock, and economic models, thus facilitating the assessment and reporting of key uncertainties** in climate, crop, biophysical, and economic dimensions of the analysis

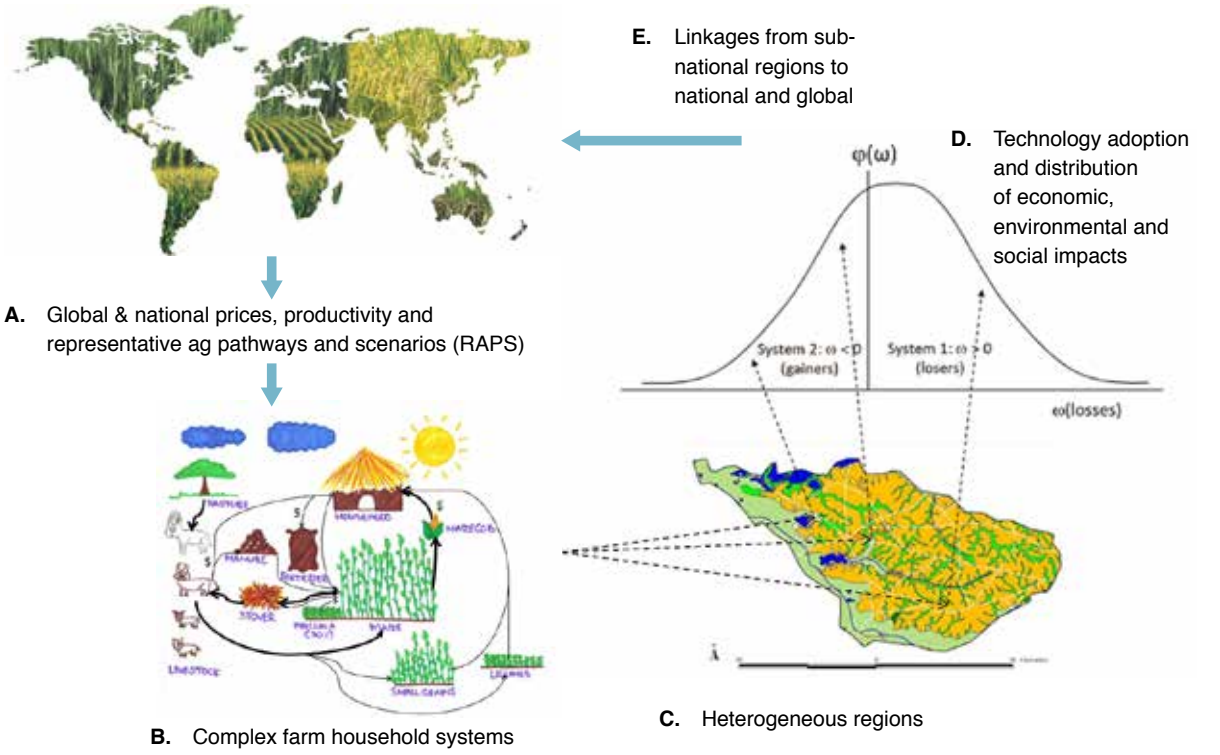


Fig 2. AgMIP Regional Integrated Assessment approach simulates climate change impact, vulnerability and adaptation through climate data, bio-physical simulation models and economic models representing a population of heterogeneous farm household systems. (A) Understand farm systems with global and national price, productivity and land use projections to define the bio-physical and socio-economic environment in which (B) complex farm household systems operate in heterogeneous regions (C). Analysis of technology adoption and impact assessment is implemented in these heterogeneous farm household populations (D). This regional analysis may feed back to the country and global scales (E) to understand how global market feedbacks in turn affect the composition, budget, and elements of rural households and agricultural systems.
(**Source:** Antle, et al. 2015).

so that they can be understood and used to interpret the results; and

- Emphasis on **capacity building in the region** so that local scientists and stakeholders can conduct regional integrated assessments.

How has the RIA been implemented?

The approach has been deployed over the past ten years in 18 Sub-Saharan Africa and South Asian countries with the support of more than 200 scientists. The RIA was applied to a complex crop-livestock production system in these regions in close collaboration with local scientists and stakeholders who were engaged early in the process for an iterative assessment of the likely impacts of climate change on agricultural systems and farmers' livelihoods. They then co-designed adaptation packages that could improve crop and livestock productivity and farmers' livelihoods as well as development pathways to help assess how the agricultural systems could respond under plausible future socio-economic and bio-physical conditions. This information was used to re-design farming systems and evaluate the benefits of these new systems in the face of changing climate (Figure 3).

This process and these findings are helping policy makers to develop actionable plans to make agricultural systems more resilient to climate change, improve food security, and reduce poverty under current and future conditions.

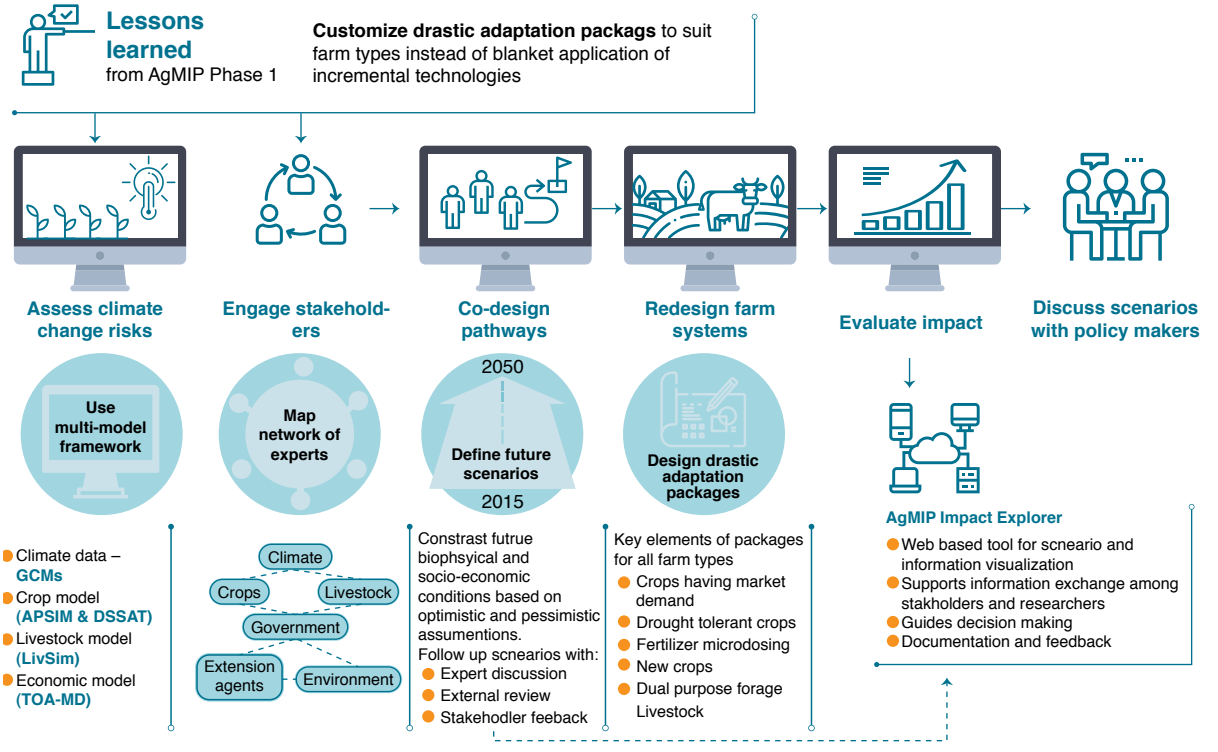


Fig 3. Customizing adaptation packages to reduce vulnerability to climate change under current and future conditions: The AgMIP regional Integrated Assessment of Climate Change Impact, Vulnerability and Adaptation of Agricultural Systems. (**Source:** ICRISAT, 2016).

Food Security in Nkayi District, Zimbabwe

Regional Integrated Assessment (RIA)

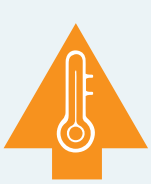
Key Messages

CURRENT FARMING SYSTEM

Smallholder farms	75% have Livestock
Rain fed	Low soil fertility
Maize, Groundnuts, Sorghum	Semi-arid
	High Food Insecurity

Nkayi district is already a poor rural area, poverty rates range between 85 to 95%. Temperatures already are beyond optimal plant growth, rainfall is increasingly irregular and insufficient. Higher temperatures; changes in rainfall and delayed start of the rainy season make agriculture more risky, greater crop failure, coupled with feed shortages for livestock. Current production levels are low, harvest outfalls endemic. Poor farmers tend to live on nutrient depleted soils, with limited response to soil amendment.

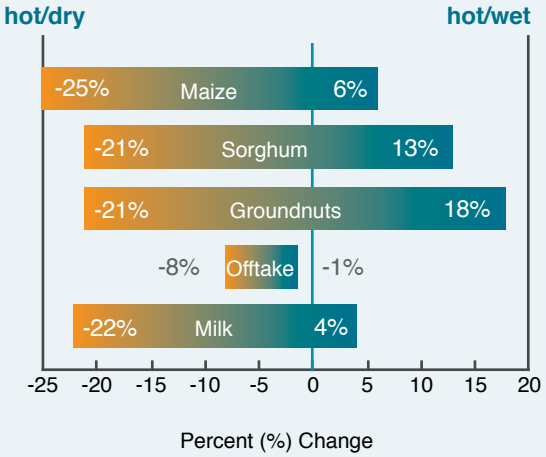
Unless government and financial partners create a more conducive environment for agriculture and market oriented support systems, climate change means greater food and nutrition insecurity for large parts of the population. Potential success depends on changing the deeper structures in the agricultural set up, not on technical change alone.



+ 2 to 3°C

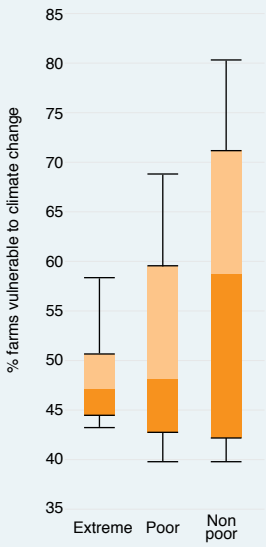
Precipitation variable: a decrease by about 25% is possible

A. Climate Risks



B. Bio-Physical Impacts

Between
39%- 85%
of farmers
are vulnerable
to Climate Change



C. Economic Impacts

Jointly with stakeholders, an integral adaptation package that prioritized removal of barriers, to accessing seed, markets, knowledge and services was developed and tested in different degrees of implementation.

Adaptation Package

	Maize	Sorghum	Groundnuts	Mucuna	Cattle	Policy intervention
	Improved cereal management		**Intensification & expansion of legumes**		**Livestock sustainability**	**Markets**
Step 1	Cropland: 76% • Improved varieties • Seed density: +30 • Fertilizer: 20kgN/ha • Manure: 1100kg/ha	Cropland: 13% • Improved varieties • Seed density: +40% • Fertilizer: 20kgN/ha	Cropland: 9%			Access to improved seed varieties
Step 2	Cropland: 49% • Improved varieties • Seed density: +30% • Fertilizer: 20kgN/ha • Manure: 1100kg/ha • Crop rotation	Cropland: 13% • Improved varieties • Seed density: +40% • Fertilizer: 20kgN/ha	Cropland: 23% • Improved varieties • Seed density: +40% • Fertilizer: 100kgP/ha • Mechanized shelling	Cropland: 14%	• Improved fodder quality and quantity	Access to improved seed varieties, technical assistance
Step 3	Cropland: 49% • Improved varieties • Seed density: +30% • Fertilizer: 20kgN/ha • Manure: 1100kg/ha • Crop rotation	Cropland: 13% • Improved varieties • Seed density: +40% • Fertilizer: 20kgN/ha	Cropland: 23% • Improved varieties • Seed density: +40% • P-Fertilizer	Cropland: 14%	• Improved fodder quality and quantity	Access to markets and market price incentives

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Benefits to Adaptation:

IMPROVING PRACTICES TODAY

Base

Current farm net returns for Zimbabwe farmers are low. These levels can be improved with a three-step approach.

Step 1

Promote and intensify drought-tolerant staple crops maize and sorghum through improved management options, including those that enrich the soil, such as inorganic fertilizer combined with greater use of better quality manure

Range of adoption: 77 - 91%

Step 2

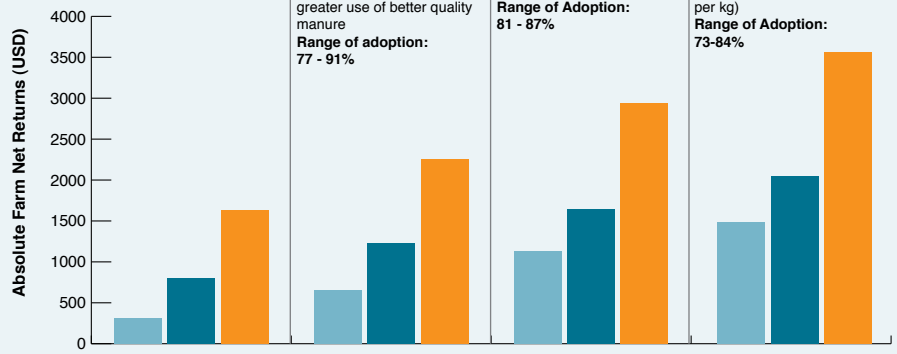
With higher maize yields from Step 1, farmers can convert land from maize to legumes – this improves soil properties, provides nutritious feed for livestock, and increases profitability per unit land

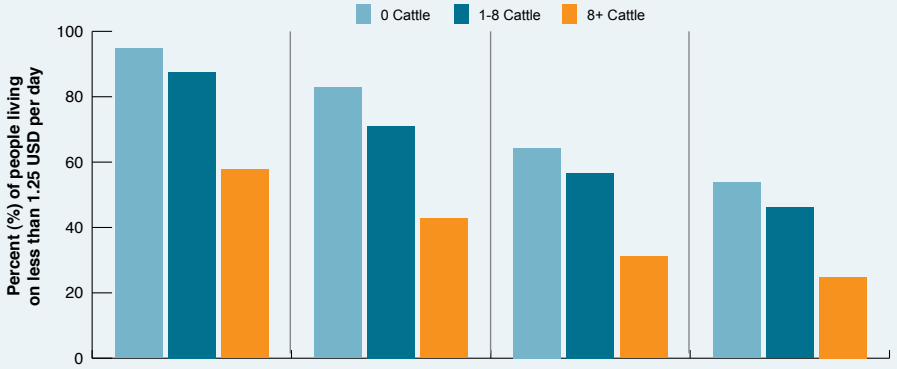
Range of Adoption: 81 - 87%

Step 3

With higher groundnut production from Step 2, farmers also use existing **market opportunities** and organize sale of groundnuts - good quality and large volumes double the price per unit sold (70ct vs. 35ct per kg)

Range of Adoption: 73-84%



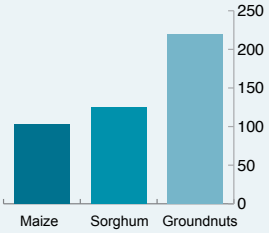


Adoption rates for these interventions would be consistently high.

Improved crop management would lead to substantial increases in crop yields.

Livestock would also benefit, from improved feed supply.

Percent (%) Change Crop Yield



Livestock Benefits

- Improved livestock **productivity**
- Increased **milk production**
- Increased **offtakes**
- **Decreased** mortality

More than **80%** of farmers would benefit from adopting the improved management package

Building sustainable futures:

Decide for one future. Stakeholders constructed future worlds, what if Zimbabwe invested in sustainable development vs fast economic growth?

- Sustainable futures: Investing in a sustainable future had clear advantages: inclusive markets and access to information that create incentives for all farmers to invest, farmers setting more land in value, diversify and intensify crops, increase herd size.

- Fast economic growth: The fast-economic growth future was reminded by the past in Southern Africa, better off market oriented would expand and invest, whereas the poor would rely on off-farm income, often become suppliers of cheap labor.

In both futures, productivity increased substantially. The main issue for climate change adaptation would be to switch to heat and drought tolerant varieties. Heat and drought tolerant varieties would benefit more under the sustainable future, and the poorest would benefit more in relative terms, though they largely remained extremely poor. Vulnerability would be higher with fast economic growth, farmers with large herds were stricken by feed gaps. Investment in sustainable development paid off, it was less risky and better for the poor.

Future Pathways and Future Adaptation:

2050s Economics Outlook: Vulnerability

Projections of driest and hottest conditions will negatively impact most farming systems. The extent of vulnerability depends on policy choices.

Following the Green Road 51% of farms may be vulnerable to climate change. **This is similar across farm types.**

51% - larger cattle herd farms
53% - small cattle herds
47% - farms without cattle

Following the Grey Road, 61% of farms may be vulnerable to climate change. Larger cattle herd farmers are more vulnerable, affected by dry season food shortage.

71% - larger cattle herd farms
63% - small cattle herds
51% - farms without cattle

2050s Economics Outlook: Adaptation

Under the driest and hottest conditions, climate change adaptation favors a switch to drought and heat tolerant varieties.

Adaptation is **easier following the Green Road**, especially for the extremely poor without cattle. **62%** of farms would take up heat and drought tolerant varieties.

57% - larger cattle herd farms
58% - small cattle herds
70% - farms without cattle

Following the Grey Road, 58% of farms would switch to heat and drought tolerant varieties. This rate is similar across all farm types.

59% - larger cattle herd farms
56% - small cattle herds
61% - farms without cattle

How AgMIP is supporting Zimbabwe's Climate Change initiatives

- Trust, confidence and continuity was established with the Ministry of Environment, Climate Change Management Department. A key officer was co-opted into the AgMIP IE panel, and has been advising on the co-design of national scenarios.
- The department linked the AgMIP-CLIP team to networks, programs and dialogues at national levels in Zimbabwe, on climate change and SDGs.
- Established links to ongoing climate change adaptation initiatives to inform how climate change adaptation options can be brought to scale, tested, verified, in such way that they respond to not only climate, but also the future state of other socio-economic and environmental challenges.
- The department requested more government staff to be capacitated in climate modeling and scenarios development, broadening the use of these approaches, and the learning capacity from implementation and verification.

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Advances in Latin America and the Caribbean

In Latin America and the Caribbean (LAC), many advances have been made to address short term climate risks in the region, and various countries have been planning and implementing incremental adaptation actions in agriculture. There is, however, an identified gap in integrating science-based information on medium- and longer-term scenarios and impacts to enable the transformations that will be required of the sector. This cutting-edge approach has yet to be capitalized upon in LAC. Doing so could significantly strengthen regional and national level public policy instruments (e.g.: nationally determined contributions, national adaptation plans, agricultural development plans, value chain strategies, etc.), while also fostering a broad participatory process to envision pathways toward a more productive and sustainable agricultural future.

Countries in the Americas can benefit from years of experience gained in other regions and the high level of technical capacity that exists to catalyze multi-disciplinary teams to conduct Regional Integrated Assessments. IICA will support its member states to capitalize on this replicable approach, strengthening capacities, managing knowledge, promoting exchange, and integrating and coordinating actors within each country and the broader region to optimize impact. The information provided by these assessments will help ensure the plans, strategies, programs and investments enhance the resilience of productions systems to climate change and maximize other productive, socio-economic, and environmental co-benefits.

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IICA´s vision is that all of its member states have access to and the capacity to use cutting edge tools and technology to enhance the resilience and sustainability of the agriculture sector under a changing climate. IICA promotes the use of data, information and analysis to ensure that the sector is able to respond to meet its multiple objectives, responding to the challenges producers face today while planning and taking action to ensure the sector is able to face future challenges.

Horizontal cooperation processes coordinated by IICA will help to accelerate the integration of these science-based tools, models and information exchange in the region.

IICA and the AgMIP have been working together since 2016 to improve the understanding of potential climate change impacts on diverse agricultural systems and to develop the capacities of public agricultural institutions and other actors to effectively use modelling tools and apply the results. They seek to promote a science-based approach to increasing the ambition and impact of climate change adaptation and mitigation commitments, strategies, and plans for the agriculture sector in IICA's member states.

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